THE

MINERAL KINGDOM.

KURR.

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THE

Mineral Kingdom

BY

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WITH

COLOURED ILLUSTRATIONS OF THE MOST IMPORTANT MINERALS,
ROCKS, AND PETRIFACTIONS.

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PREFACE.

In introducing his book to the German public, Dr. Kurr has explained that he neither wishes the Plates to take the place of a collection of minerals, nor the descriptions of them to be considered as a hand-book of Mineralogy. It must be evident that to obtain anything like a scientific knowledge of the subject, much preliminary study is required, and a familiar acquaintance with the minerals themselves; but, on the other hand, a collection of minerals is in itself but slightly interesting to the uninitiated, while a scientific treatise is necessarily so full of technical expressions and other hard reading as to make the study of it uninviting to the beginner. The aim of the author has therefore been to produce something that would prove interesting to his readers, and incite them to become students of Mineralogy in the proper sense of the term, and to furnish the young collector with representations of some of the more rare and expensive specimens. It may be thought that this might have been better attained by adopting a still more popular style, but this could only have been done by laying every one who may be induced to prosecute the subject further under the very great disadvantage of having, as a preliminary, to throw away all that he had acquired,—a consequence of all the pseudo-popular science so common in the present day.

The Plates speak for themselves, and every one qualified to judge will testify to their beauty and fidelity.

The work of the Editor has been little more than that of simple translation and comparison with British authorities. On many occasions, native localities have, however, been added, and generally, he has endeavoured, by such slight alterations and additions as seemed necessary, to render the book more suitable to the English reader.

He begs, in conclusion, to acknowledge the assistance he has derived in his labours from the excellent "Manual of the Mineralogy of Great Britain and Ireland," by Messrs. Greg and Lettsom,* a work of which he cannot speak in too favourable terms.

* J. Van Voorst, London, 1858.

Edinburgh, *January* 1*st*, 1859.

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INTRODUCTION.

THE Natural History of the Mineral Kingdom comprises, in its widest signification, the inorganic fixed bodies which form the earth's crust. Mineralogy, in a narrower sense, treats of the simple minerals, Geognosy, of masses of rock presented as a whole, while Geology is occupied with the theory and history of the formation of the globe. Most minerals are fixed or solid, and characterised by peculiarity of form, appearance, weight, hardness, lustre, colour, etc. They are inanimate, having their origin in chemical activity and the physical forces, and present no traces of organic structure. They are under the influence of no relations to climate, and although they sometimes occur in conditions which admit of their being dissolved in the atmosphere, or of their being decomposed, yet, in comparison with the organic bodies of the earth, they present a certain permanence and durability, so that when we wish to produce anything durable either in art or in industry, we usually have recourse to the products of the mineral kingdom.

FORM OF MINERALS.

As regards the relations of form, we find in simple minerals either very regular many-sided bodies, which are called CRYSTALS, or irregularly shaped forms, which are not crystallised. Crystals are bounded by a certain number of planes or faces, edges and angles, the form, position, and extent of which are subject to the laws of symmetry.

The crystalline *planes* are in general smooth, as all the figures in Plate A show, and only exceptionally striated, either in the line of certain edges, as in Plate B, Fig. 2, vertically, as in Fig. 5, or horizontally, as in Fig. 6. They are also occasionally covered with smaller crystalline planes, the arrangement of which is said to be glandular, as in Plate B, Fig. 4, scalariform, or ladder-like, as in Plate XI., Fig. 21, etc.; more rarely, they are sometimes curved, as in Plate B, Fig. 1, and Plate I., Fig. 4. According to the number of their *sides and angles* we distinguish—

I. The Square, or four-sided figure; and further,

- *a.* The Square, or equal-sided rectangular parallelogram. Plate A, Fig. 1.
- *b.* The Rhomb, or equal-sided oblique angled parallelogram. Fig. 3.
- *c.* The Rectangle, or unequal-sided rectangular parallelogram. Fig. 5.
- *d.* The Rhomboid, or unequal-sided oblique angled parallelogram.
- *e.* The Trapezium, or unequal-sided square, with two parallel sides. Fig. 9.
- *f.* The Trapezoid, in which every two adjacent sides are equal to one another.

II. The Triangle, or three-sided figure.

- *a.* The equal-sided, or regular triangle. Fig. 13.
- *b.* Isoceles triangle, with two sides equal. Fig. 15.
- *c.* Unequal-sided triangle, with three unequal sides. Fig. 17.

III. The Pentagon, or five-sided figure. Those examples which occur in the mineral kingdom are irregular, so that one side is generally larger than the other four. Fig. 19.

IV. The Hexagon, or six-sided figure, may be regular, as in Fig. 21, having six equal sides cutting each other at equal angles; or irregular, in which case the angles are usually of two kinds.

V. The Octagon, or eight-sided figure. Fig. 23.

VI. The Dodecagon, or twelve-sided figure, Fig. 25, etc. This occurs almost always in composite forms, and presents corresponding variations.

According to the *number* of planes we recognise—

I. The Tetrahedron, bounded by four triangular planes. Plate XV., Fig. 17.

II. The Hexahedron, bounded by six square faces. Plate A, Figs. 2, 6, 8.

III. Octahedron, bounded by eight triangular faces. Plate A, Figs. 11, 16, 18.

IV. Dodecahedron, bounded by twelve faces. Plate A, Figs. 4, 20.

V. Icosahedron, bounded by twenty faces. Plate XVII., Fig. 8.

VI. Trapezohedron, bounded by twenty-four faces, each of the form of a trapezium. Plate A, Figs. 10, 12.

VII. Hexakisoctahedron, bounded by forty-eight scalene triangles. Plate B, Fig. 1.

The *position* of the planes gives rise to the following distinctions :—*Terminal* or *basal* planes occur only in such crystals as have a greater or smaller extension in one or two directions ; the same remark applies to the *lateral* planes which unite the terminal planes, and form the sides of the crystal when it is viewed in an upright position. Those planes of composite crystals which end in a terminal angle or edge are called *vertical* planes. *Original* or *primary* planes are those which belong to the primary form of a body ; *secondary* planes, or planes of combination, are those which exist in derived forms, such as are produced by truncation of the edges, angles, etc. Thus, for example, in Fig. 8, Plate B, the cube is the primary form, and its planes are marked P. The planes lying on the edges, D, are secondary planes, whose origin is the even truncation of the edges. Now, as the cube has twelve edges, and as these secondary planes are subject to the law of symmetry, it follows that all the edges of the same kind must be truncated. In Fig. 7, the primary form, a regular octahedron, is changed, its angles being so truncated that the cube predominates ; the planes of the octahedron are marked O, those of the cube P. If the planes of the cube be again increased, the planes of the octahedron will entirely disappear, and the derived form of the cube will have completely replaced the primary form of the octahedron. This is frequently exemplified so far in the case of fluor spar. Fig. 9 represents an example of oblique disposition of the secondary planes, and Fig. 10 gives another of double truncation or sharpening of the angles of the cube.

Edges are the right lines in which two planes meet. A solid, with all its edges alike, is called single or equal-edged, as in Plate B, Fig. 2 ; with two kinds of edges (Fig. 12), is said to be double-edged, and so on. In Fig. 12, those edges which lie between the basal and lateral planes are called *basal* edges, those between the lateral planes are called *lateral* edges. In Fig. 5, the three edges converging in the terminal angle are called the *vertical* edges, those running vertically, the *lateral* edges, and those between the terminal and lateral planes, the *basal* edges. According to the direction in which two planes meet in an edge, edges are distinguished as *acute*, *obtuse*, and *rectangular*, the angle of direction being ascertained by means of an instrument called the goniometer.

Angles are the points in which three or more edges meet. According to the position we distinguish terminal angles, basal angles, and so on. For example, in Fig. 3, Plate B, the upper and under ones are *terminal* or *vertical* angles, the four others united by the basal edges are called *basal* angles.

Axes.—Those right lines are called axes, which in imagination so pass through the centre of a crystal, that its planes, edges, and angles, are grouped in equal masses around it. In many bodies there are three, and in a smaller number four axes admitted as giving measurements. All the essential peculiarities of crystals depend upon the length and position of these axes. The systematic classification of all crystals has therefore been founded on the relations of their axes, as given below.

I. Monometric or Tesseral Solids, with three equal axes intersecting each other at right angles. To this system belong—

a. Simple elementary forms.

1. The Cube, hexahedron, or quadratic hexahedron. Plate A, Fig. 2.
2. The regular Octahedron. Plate A, Fig. 14.
3. The Rhombic Dodecahedron, or granatoid. Plate A, Fig. 4.

b. Hemihedral forms.

4. The Tetrahedron, or hemi-octahedron. Plate XV., Fig. 17.
5. The Pentagonal Dodecahedron, or pyritoid. Plate A, Fig. 20.

c. Derived Crystals.

6. The Leucitoid, or Trapezohedron. Plate A, Fig. 12.
7. The Parallel, or Pyritohedral Hemi-hex-octahedron. Plate A, Fig. 10.
8. The Trigonal Trisoctahedron. Plate I., Fig. 2.
9. The Pyramidal Cube. Plate X., Fig. 17.
10. The Icosahedron. Plate XVII., Fig. 8.
11. The Hexoctahedron. Plate B, Fig. 1.

This system further includes all modified forms of the primary solids above mentioned, such as are produced by truncation of the edges and angles. For example, the cubo-octahedron, Plate B, Fig. 7 ; the cubo-dodecahedron, Fig. 8 ; the cubo-pentagonal dodecahedron, Fig. 9 ; the cubo-leucitoid, Fig. 10 ; the double tetrahedron, Plate XV., Fig. 18 ; the pyramidal tetrahedron, Plate XXI., Fig. 6, and so on.

II. Dimetric Solids, with a vertical axis longer or shorter than the two equal transverse axes, which are perpendicular to one another, and to the vertical axis. This system includes the following forms :—

1. The Square Octahedron. Plate B, Fig. 3.
2. The Right Square Prism. Plate B, Fig. 12. And of derived forms, the hemihedral square octahedron.

III. Trimetric Solids, with three unequal axes intersecting each other at right angles—

1. The Rhombic Octahedron, figured in Plate XII., Fig. 1, with truncation of the vertical and upper basal edges.
2. The Right Rhombic Prism. Plate B, Fig. 13.
3. The Right Rectangular Prism, Plate A, Fig. 6, and the rectangular octahedron derived therefrom.

IV. Monoclinic Solids. All the axes are unequal, two of them are perpendicular to one another, the third forms with one of these an oblique angle. This system includes—

1. The Oblique Rhombic Prism. Plate B, Fig. 14.
2. The Oblique Rectangular Prism, Plate X., Fig. 7, and the oblique rhombic, and oblique rectangular octahedrons derived from these.

V. Triclinic Solids, with three unequal and oblique axes. This system includes—

The Oblique Rhomboidal Prism, Plate B, Fig. 15, with its combinations.

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VI. Hexagonal Solids. These have four axes, three of them lying in a plane, and intersecting each other at equal angles (60°), but they are perpendicular to the fourth or vertical axis. This system includes—

1. The Rhombohedron. Plate B, Fig. 16.
2. The Hexagonal Prism. Plate A, Fig. 22.
3. The Hexagonal Double Pyramid, Plate III., Fig. 1; and its derived forms, such as the quartzoid, Plate III., Figs. 3 and 6; the hexagonal plate, Plate XII., Figs. 5, etc.; the twelve-sided prism, Plate A, Fig. 26; and the scalenohedron, or hexagonal, unequal-edged, double pyramid, Plate VII., Fig. 11.

Crystals, with a vertical axis of a variable length, are called *open* forms; when the vertical axis has a determined length in relation to the transverse axes, they are called *closed* forms. The former are always *prismatic*, that is, they crystallize in four, six, eight, or twelve-sided prisms, the lateral planes and edges of which lie in the direction of the vertical axis. The closed solids are also called *pyramidal*, when the planes are inclined towards the vertical axis, and terminate in an angle or vertex. Thus, the different octahedrons, rhombohedrons, and their combinations, are pyramidal bodies. All the solids of the tesseral system, whose axes are equal and perpendicular to one another, are called, on the other hand, *regular* or *spherohedral;* they have the appearance of a prism, or of a pyramid.

IRREGULARITIES OF CRYSTALS.

Irregularities of crystals occur in all the systems. Sometimes single planes, and sometimes certain pairs of planes, are more or less extended at the expense of others, an instance of which may be observed in the druses of quartz, Plate III., Figs. 6 and 7, where in single crystals (Fig. 7) one of the pyramidal and two of the prismatic planes are so extended as partially to remove the others. The planes of combination of truncation also sometimes present similar appearances, so much so, indeed, that they are either of unequal size, or have in part quite disappeared.

The union of half or of whole crystals is called *twin* composition. The two parts may be parallel with the vertical axis, as in Plate V., Fig. 2, or cross each other in any way, as in Plate V., Fig. 5; Plate I., Fig. 23; Plate XVII., Fig. 14, etc. Two or more such twins are often joined to each other, as in Plate VI., Fig. 4; Plate I., Figs. 19 and 20.

Aggregations of crystals form either *druses*, Plate III., Figs. 5, 6, and 7—a term which implies irregular aggregations generally, or they are *notched, arborescent*, or *dendritic* forms. Plate XV., Figs. 7, 8, and 13; Plate XIV., Figs. 2, 5, and 10. Sometimes they pass into *laminated* tables or plates, Plate XIV., Fig. 4; into bar-like plates, Plate XIV., Fig. 1; and also into *filiform* or *capillary* forms, as occurs in the native metals, and in many ores. At other times they are found in the form of long needles, which are not uncommonly arranged in bundles (*acicular crystals*), Plate XVI., Figs. 8 and 11; *radiating foliated*, as in Plate XVI., Fig. 7; and *concentric radiated* forms, as in Plate XVI., Fig. 10, also occur, as well as compact *wedge-like* pieces, Plate XX., Fig. 22.

Pseudomorphs are those crystalline bodies whose internal constitution and elements do not correspond to the external form. They are partly formed by *alteration*, as, for instance, crystals of pyrites which are changed into brown and red ironstone, by having given off their sulphur and taken up instead oxygen and water, or the former alone. Another example is presented by a small crystal of any mineral which is so incrusted by, or imbedded in another, as to be quite invisible, or at last to have entirely disappeared. Instances of this kind are called pseudomorphs by *incrustation*. Cases where the space, which has been occupied by another crystal, is so filled by a foreign mineral as to produce almost a copy of the former, present a third form of pseudomorphism, and are called pseudomorphs by *substitution*.

NON-CRYSTALLIZED IRREGULAR FORMS.

Although all true minerals which exist either as simple elements or exhibit fixed chemical composition, occur crystallized, there are, nevertheless, many which present quite irregular, or completely shapeless masses, or such forms as cannot be reduced to crystals; such are the *globular*, *botryoidal*, *reniform* masses. Many of these, such as Carrara marble, internally present traces of crystalline structure, and are therefore said to be *crystalline;* some, on the contrary, present a perfectly clear, glass, or resin-like fracture, as, for example, the opal, Plate IV., Figs. 19, 20, or amber, Plate XII., Fig. 6, and these are called *amorphous*. Others again are earthy, readily part with colour, and are easily crumbled into dusty particles, as, for instance, ochre, clay, chalk, etc.

It is clear that the purposes to which a mineral may be applied must, in many instances, depend upon these different conditions of aggregation; and all the internal relations, which are readily made apparent by breaking or tearing minerals, are comprehended under the names of *Structure* and *Fracture*. It is evident that those bodies which are derived from the vegetable kingdom, as, for example, many resins and coals, Plate XII., Figs. 6-13, have retained their original form with the corresponding structure, and this also is true as regards particular petrifactions.

HARDNESS.

The hardness of any mineral may be best tested by a cutting instrument, such as a knife, steel, or file, or by a mineral whose hardness is already determined; and as the expressions half-hard, hard, and very hard, are always indefinite, the newer method introduced by Mohs is to be specially commended. His scale is the following:—

1.	Degree;	Hardness of	Talc.
2.	,,	,,	Gypsum.
3.	,,	,,	Calcite.
4.	,,	,,	Fluor Spar.
5.	,,	,,	Apatite.
6.	,,	,,	Feldspar.
7.	,,	,,	Quartz.
8.	,,	,,	Topaz.
9.	,,	,,	Sapphire.
10.	,,	,,	Diamond.

These bodies having been tested in the form of crystals, the results given have been arrived at by the harder body cutting the softer. The degrees of hardness, 1, 2, and 3, may be proved by the finger nail, 1 to 6 by a knife; 6 to 10 give out fire when struck by a steel, and produce from the file a sound more or less harsh.

SPECIFIC GRAVITY.

Specific gravity means the weight of a body in relation to its own volume. It is, however, generally applied to the weight of any body as compared with that of an equal bulk of distilled water. It is ascertained by first weighing the body in the atmosphere, and then under water, and by dividing the first found absolute weight by the difference, which is really the weight of the displaced water. For this purpose minerals are used which have been reduced to small fragments, and if they are porous, in the form of powder, and the experiment is made at a mean temperature of 60° Fahr. It is well also to repeat the weighing several times, in order to secure a delicate balancing and an exact weight. Experience shows that the metalloids, and some combustible minerals derived from the vegetable kingdom, present the lowest specific gravity, from 0·5 to 4·9; the ordinary earthy minerals vary from 2 to 3, the precious stones from 2·8 to 4·6; the ores and heavy metals from 4 to 24.

CHARACTERS DEPENDING ON LIGHT AND COLOUR.

Optical Deportment of Minerals.

Many minerals, and especially such as are crystallised, are perfectly *transparent*, some are only *translucent*, while others, such as the metals, are quite *opaque*. Transparency is generally considered as a mark of purity.

If a ray of light falls on a transparent body, it is more or less *refracted*, that is to say, diverted from its course; in many bodies, however, such as calcite, gypsum, etc., the ray divides into two parts, so that the image of an object placed under it appears double, as is seen in Plate B, Fig. 17. This is a prism of Icelandic double-refracting spar, whose fissured edges have been polished to smoothness. Under it is placed a representation of two rings, which, when observed from before, appears doubled and somewhat displaced. If the prism be moved over the picture to the right or left, the rings are displaced differently, and it is observed that the two entering rays of light present a different divergence.

When thinly-cut plates of transparent crystals are seen in *polarised* light, for example between crossed plates of transparent tourmaline, which have been cut parallel to their axes, splendid rings of colour are seen, which, in each mineral, present something peculiar, so that all bodies having a single optical axis, as for instance, calcite, or, in a wider sense, all monometric and dimetric figures present similar images to that shown in Fig. 18, Plate B, which is a representation of calcite cut perpendicularly to the axis. If the tourmaline plates are laid parallel, there appears in such minerals, instead of a dark cross, a white one, as seen in Fig 19, and the rings present the complementary colours of those of the former image; in place of red there is green, blue is replaced by yellow, and so forth. If two such mineral plates are crossed at right angles, there appears, instead of the dark cross in the middle, an S-shaped fourfold figure. If the mineral, rock crystal for instance, is compressed by a screw, the circles of colour are distorted into parabolic figures, while, at the same time, the elasticity of the rock crystal is resisted. Crystals having two axes, such as trimetric, monoclinic, and triclinic bodies, under this arrangement present other appearances and colours, as in Figs. 20 and 21, which are taken from crystals of saltpetre.

The *colours* which minerals present in ordinary light are fixed or essential to every mineral if they depend on its chemical composition; they are accidental if they only arise from known impurities, or from non-essential mixtures. Thus, for instance, rock crystal is colourless; in the amethyst, however, it is combined with oxide of manganese. In the same manner most coloured precious stones derive their colour from the metallic oxides; the red from the oxides of manganese and iron, the blue and green from the oxides of copper and chrome. A glance at the plates will show that in others all the colours in the mineral kingdom are found, simple as well as mixed; and that they occur in the most varied shades and shapes may be seen in Plates III. and IV.

The metals, and many ores, have particularly striking colours, and possess the property known as *metallic lustre*. We make use of the expressions gold-yellow, brass-yellow, silver-white, tin-white, lead and iron-grey, all derived from the colours of the corresponding metals.

The *streak* is proved by scratching with a knife, or by rubbing off colour on a rough fragment of porcelain, and often affords a very good means of distinction between many allied substances, as, for instance, between the oxide of iron or magnetic ironstone and brown iron ore, the different ores of manganese, etc.

There are other peculiarities of colour, which are sometimes accidental and sometimes characteristic, such as play of colour, iridescence, change of colour (see Plate VI., Figs. 9 and 10), dichroism, or the property of having different colours when viewed in two different directions (Plate X., Fig. 17), and variegated or dove-necked tarnished surfaces (Plate XVII., Fig. 2).

The *lustre* may differ in such degree and quality, from strongly to slightly lustrous, splendent to dull, as is expressed by terms like the following: adamantine, vitreous, resinous, pearly, silky metallic lustre, and the like.

RELATION OF MINERALS TO ELECTRICITY, MAGNETISM, AND HEAT.

Many minerals become electric on being rubbed, such as tourmaline, sulphur, anthracite, and numerous others, some exhibiting *positive*, and others *negative* electricity. Some, especially the native metals, and many varieties of quartz, conduct electricity; others, such as felspar, and similar oxidised combinations, are non-conductors; while others, again, on being heated, exhibit *polar electricity*, so that one end of the crystal is positive and the other negative. The examination is effected by means of the electrometer, or by an animal hair fastened to a piece of

glass. As the electric relations of the elementary bodies exercise the greatest influence on their chemical relations, it may be stated generally, that the metalloids and acid-forming metals are electro-negative, and that the other base-forming bodies are electro-positive.

A few iron ores exhibit magnetic properties, and indeed the compact magnetic ironstone not only attracts such bodies as are being capable of being attracted by the magnet, but sometimes possesses the power of making those magnetic. Besides native iron, titanic iron, magnetic iron ore, and magnetic pyrites, nickel and cobalt, as they are obtained by reducing their ores, are also capable of being attracted by the magnet. The experiment may be tried either with the electrometer, or with an artificial magnet, which can be made at any moment, by rubbing a knife, or other steel instrument, with a natural or artificial magnet.

Heat expands all minerals more or less; the native metals are affected by it to the highest degree, the crystallised compact oxidised substances to a somewhat smaller extent. This peculiarity is specially to be borne in mind in finding specific gravities, hence it is usual to maintain the temperature at a mean of 60° Fahr., or to reduce the results to 32°. Many minerals melt on being heated, and their *fusibility* may be determined either by comparison with other known substances, or by the thermometer. Others volatilise or burn on being heated, as is shown by their deportment before the blowpipe and in the retort. It must, however, be borne in mind, that the admission or exclusion of air exercises a very powerful influence on the results.

CHEMICAL RELATIONS OF MINERALS.

Minerals are either simple or compound; the former are called elementary, the latter compound bodies. The number of elements, according to the latest discoveries, has gradually increased to sixty-four, whereof, however, only some two-thirds play an essential part in the mineral kingdom, and of these, again, only a few enter into the composition of rocks.

In the following table a view of these bodies is given, together with their properties and appearances, and at the same time their chemical symbols and equivalents, or atomic weights, are appended; their electrical relations are also indicated in the following manner:—

1. Those bodies which exhibit negative electricity are marked —, and usually form acids with oxygen; to these belong the metalloids without exception, and many of the allied metals.

2. Those which exhibit positive electricity are marked thus +, and form bases with oxygen.

3. Those + — or — +, form with oxygen sometimes bases and sometimes acids. The combining proportions, or *equivalents*, of the simple bodies, are those proportions by weight in which they combine, or have combined with others; and it is usual to calculate these from hydrogen, the atomic weight of which is set down as 1, or from oxygen, the weight of which is taken at 100. It is also usual, for the sake of brevity, to employ the *symbol* of each element indicated, and this usually consists of the initial letter of its Latin name. Thus, for example, the equivalent of hydrogen is 1, that of oxygen is 8; then water, the commonest and first compound of these two elements, consists of one equivalent of hydrogen, and one equivalent, or eight parts by weight of oxygen; in the deutoxide of hydrogen, on the other hand, there are two equivalents or sixteen parts by weight of oxygen; the chemical formula for water must therefore be HO, or it may be more shortly expressed by putting down one equivalent of hydrogen, and setting over it a point, thus, $\dot{H}$; that for deutoxide of hydrogen must be HO_2, or $\ddot{H}$. Thus, further, one equivalent of sulphur, 16, unites with one equivalent of oxygen, 8, and with it forms its first oxygen compound, hyposulphurous acid, SO, or $\dot{S}$; with two equivalents of oxygen, it forms sulphurous SO_2 or $\ddot{S}$, and with three of oxygen, sulphuric acid, SO_3 or $\dddot{S}$. It follows as a consequence, that in all combinations of sulphur with oxygen the amounts of oxygen are in simple proportions to one another, that is, they are double, triple, or the like multiples of the first simple combining number; this is called the law of multiple proportions. The same law holds with all other combinations, simple or compound, which may be estimated in a similar manner, according to the number of equivalents of oxygen, hydrogen, or sulphur.

The oxygen compounds, or oxides, as they are called, play an important part in nature generally, insomuch as the mineral elements composing the greatest part by bulk of the earth's surface are oxides, such, for example, as the clays, limes, siliceous and talcose earths, water, etc.; while, on the other hand, the pure elements, such as carbon, sulphur, and the native metals, only enter into it in smaller quantities, and the compounds of chlorine and sulphur are almost invisible.

The oxides are divided, as above mentioned, into *bases*, like the earths, alkalis, and basic oxides of the heavy metals, and *acids*. The former always contain a smaller quantity, one, one and a half, or at most two equivalents of oxygen; the latter, one and a half, two, two and a half, three, or five equivalents of oxygen; and in doubtful cases, the compounds containing more oxygen, like the more negatively electric bodies, are generally considered acids.

The compounds of sulphur with the heavy metals are called generally sulphur ores, and more particularly pyrites, and glance, if they present a metallic lustre, or blendes and cinnabars, if they are clear and of adamantine lustre. The same law of composition holds here as with oxygen, so that if a body, P, unites with one equivalent of oxygen in the oxide PO or $\dot{P}$, it also unites with one equivalent of sulphur, and forms with it the metallic sulphuret PS or $\acute{P}$. It is usual, for shortness, to distinguish such compounds of sulphur with a dash over the initial letter of the element, and two equivalents of sulphur with two dashes, while double equivalents of the element may be expressed by a dash through its initial letter P. Thus, if Fe represents iron, Fe_2 may be indicated by $\bar{F}e$.

For further details reference must be made to any of the chemical and mineralogical text-books.

As the purposes to which minerals may be applied, as well as the knowledge of individual species, stand in very close relation to their chemical composition, it is important to acquire dexterity in the analysis of minerals, and for this purpose either the moist or dry method may be

employed. The latter consists principally in the application of the blowpipe, the former in the solution of bodies in water, acids, etc., and the application of certain re-agents by which precipitates of particular colours and conditions are thrown down. In both cases the object is either to obtain decomposition or new combinations, which may once more be analysed.

In using the *blowpipe*, small fragments of the mineral may be held either on charcoal or in platinum forceps, so that first the fusibility, and then the escaping vapour, or the deposit left on the charcoal, as well as the residue, is examined, either by reducing it in the inner flame, or by forming from it, along with borax, soda, and salt of phosphorus, a pearl-like drop, which is also to be considered with reference to its colour and appearance. It is to be kept in mind, in using the blowpipe, that the point of the flame has an *oxidising* power, and the inner blue cone has a *reducing* influence, that is, it has the power of deoxidising; also, that metals easily fused or reduced should not be held in the platinum forceps. Many bodies, such as chalk, become exceedingly brilliant when heated, others colour the flame at once, or after being held in it for some time. Thus, for example, all calcareous minerals colour it vermillion-red, strontium gives a brilliant purple-red, lithium a pale purplish-red, potassium a violet, sodium a pure intense yellow, baryta a green, boracic acid a pale green, acetate of copper a green, chloride of copper a blue, and the presence of chlorine may be easily distinguished in this way by the addition of some oxide of copper; while, on the other hand, the presence of copper, be it of ever so small amount, may be easily recognised by the bright blue flame on moistening the test with a drop of hydrochloric acid. The colour which certain metallic oxides impart to a bead or pearl of borax, which has been obtained by burning on charcoal, when heated on a platinum wire, is likewise important. Thus, the oxide of cobalt colours it blue, the oxide of copper imparts a green colour, and, if a granule of tin is added, it becomes red, peroxide of iron makes it yellow when hot and an olive-green when cold, protoxide of iron gives a grass green, oxide of chromium an emerald green, oxide of manganese an amethyst red, oxides of manganese and iron together give a blood red or garnet colour, and so on; while the oxides of zinc, lead, and bismuth, do not change the colour of the bead. Further details will be found in the descriptions of the individual minerals. The analysis by water is best performed in a closed glass tube, or in a small retort over a spirit lamp, by which means small drops are deposited on the colder part of the tube. This experiment serves at the same time to distinguish the water from the carbonic acid, both of them producing small beads in the borax pearl.

The presence of carbonic acid is best recognised in the moist way, by solution in hydrochloric and nitric acids until effervescence takes place.

Sulphur and sulphuric acid may be detected by using finely-powdered specimens along with soda in the inner flame, by the aid of which a sulphuret of soda is produced, and this, when moistened by a drop of water, and brought into contact with a silver coin, leaves a brown stain, and gives off an odour of rotten eggs (sulphuretted hydrogen).

The presence of siliceous earths is best ascertained by melting the powdered mineral along with borax or soda, while to the clear pearl which is formed there is to be added salt of phosphorus; and thus, after continued heating, the siliceous earths may be recognised in the shape of beads or points. The analysis by the moist way may be performed either with acids or water.

Water can only dissolve a few natural salts, as, for example, rock salt, alum, carbonate of soda, sulphate of soda, potass, salts of magnesia, protoxide of iron, oxides of copper and tin, and lime; the solution of each of these has a peculiar taste, and when evaporated in a watch-glass, leaves behind the dissolved salt, which may now be readily analysed by the ordinary chemical process.

The acids act on several compounds of silica, especially such as contain water (the hydrous silicates), as, for instance, the zeolite; they have also a solvent action on calcareous felspar, so that the silica separates like a jelly or slime; other silicates must first be melted, or mixed with alkalis, if they are to be further examined. On the other hand, the acids dissolve most metallic oxides with a determined colouring, which is indicated to some extent in the accounts of the individual minerals.

RELATIONS OF THE CHEMICAL CONSTITUENTS TO CRYSTALLINE FORMS.

Each mineral, the chemical composition of which has been determined, appears, when viewed externally, to be physically and crystallographically endowed with the same properties, so that not only the hardness, weight, colour, and lustre, but also the form of the crystal, show a certain constancy. There are instances, however, in which the same chemical compounds, or even simple bodies, crystallise in two or three different primary forms, and under these circumstances, the hardness and weight also present modifications. Such bodies are called *dimorphous* or *trimorphous;* the oxide of titanium, $\ddot{T}i$, which occurs as rutile, anatase, and brookite, offers a fine example of this, as well as sulphuret of iron, sulphur, and even a few metals. On the other hand, different, but chemically related elements often present very harmonious relations of form, so that, in their composition, the one may be totally or partially substituted for the other, and the crystalline form remain unchanged; this is called *isomorphism.* Thus, for example, magnetic iron ore, composed of like equivalents of the protoxide and peroxide of iron, is isomorphous with octahedral titanic iron, chromic iron, franklinite, galenite, or zinc spinel, and generally with the spinel. In all there is a one-atom base, RO or $\dot{R}$, with one equivalent of a one-and-a-half-atom negative constituent, $R_2 O_3$, or $\ddot{R}$, and all crystallize as regular octahedrons. The protoxide of iron is sometimes replaced by oxide of tin, sometimes by magnesia, the peroxide by oxide of titanium, oxide of chromium, or alumina. There are many similar examples of this; many bodies, moreover, occur both in the *amorphous*, or glassy, and compact form, in the gaseous or vapour-like condition of aggregation, or in a state which admits of their transformation thereinto.

I. METALLOIDS, NON-METALLIC ELEMENTS.

A. Gaseous Metalloids.

Name. English.	Name. Latin.	Symbol.	Electrical Relations.	Atomic Weight or Equivalent O = 100.	Atomic Weight or Equivalent H = 1.	Specific Gravity.	Colour and Appearance.	FURTHER PROPERTIES AND MODES OF OCCURRENCE.
1. Oxygen.	Oxygenium.	O.	—	100	8	1·19926	Colourless, inodorous, and tasteless.	Found in all oxides, in atmospheric air to the extent of 21 parts in 100 by volume, or 23·3 per cent by weight; in water, to the extent of 1/3 of its volume, or 88·9 per cent of its weight. Not combustible, but supports combustion.
2. Hydrogen.	Hydrogenium.	H.	+	12·5	1	0·06933 14½ times lighter than air.	The same, but very impure and unpleasant to the taste.	2 vols. with 1 vol. O, or 11·1 H, with 88·9 O, form water, which is contained in many minerals, as crystallized water and hydrated water, and is widely distributed over the earth as ice, snow, and in a fluid state. It forms acids, with Cl., Br., I., and Fl. Inflammable and combustible, but does not support combustion.
3. Nitrogen.	Nitrogenium.	N.	—	175·06	14	0·9706 14 times heavier than hydrogen.	The same.	Not supporting combustion, and not inflammable; forms 0·79 parts by volume of atmospheric air, and occurs only in salts of nitrogen and ammonia, such as the anthracite of the upper surface of the earth, also in the organic remains (petrifactions) of the stratified rocks. Is respirable when mingled with oxygen.

B. Condensible or Fluid Metalloids.

4. Chlorine.	Chlorum.	Cl.	—	443·28	35·4	1·33	Light yellow gas, or greenish-yellow fluid.	Has a suffocating odour, is soluble in water, forms acids with hydrogen and oxygen, is found in rock salt, and in the metallic chlorides especially, as the chlorides of silver, lead, copper, etc.
5. Bromine.	Bromium.	Br.	—	999·62	78·4	2·99	Deep brownish-red fluid.	At 13° below zero crystallises into metallic-looking firm crystals, forms acids with oxygen and hydrogen. Is found in small quantities in bromide of silver, and chloro-bromide of silver, in rock salt, in many bitterns and mineral springs, also in sea water, chiefly in combination with magnesium.
6. Fluorine.	Fluor.	Fl.	—	233·80	19	...	...	Forms acids with hydrogen, with silicon hydrofluosilicic acid. Is found as a metallic fluoride in fluor-spar, krysolite, topaz, wavellite, apatite, some phosphates of lead, and in various kinds of mica.

C. Fixed or Solid Metalloids.

7. Carbon.	Carbonium.	C.	—	75·415	6	2·4 in graphite 3·55 in the diamond.	Iron-black, hexagonal, or colourless, octahedral, and transparent.	Dimorphous, as graphite very soft, and leaving a black streak on white paper, as the diamond the hardest of known bodies. Burns in oxygen and atmospheric air to carbonic acid, which also streams out of the earth as a gas; is contained in many mineral springs, in river and sea water; it also occurs in combination with many bases, as, for example, lime, baryta, strontia, soda, magnesia, etc. It is contained in abundance in coal and other organic substances.
8. Boron.	Boron.	B.	—	136·20	10·8	...	Transparent, lustre adamantine, yellowish crystals, or graphite-like and hexagonal, also amorphous, of a chocolate-brown colour. The first form has the hardness of the diamond.	Forms boracic acid, $B.O_3$, with oxygen, which sometimes exhibits basic properties. It sometimes occurs free (as in sassoline), sometimes in combination with soda, magnesia, lime, etc., in tincal, boracite, datolite, etc.; it is also found in some mineral springs. It is in general but sparingly distributed in nature.
9. Iodine.	Iodium.	I.	—	1586·0	126	4·948	Greyish black, lustre metallic, translucent, rhombic.	Evaporates in the atmosphere and in heat; smells like chlorine; forms acids with oxygen and hydrogen, with the metals iodides. Is found sparingly in the iodides of silver and mercury, in sea water and many mineral springs; also sometimes in rock salt, especially as iodide of magnesium.
10. Phosphorus	Phosphorus.	P.	—	392·28	31·4	1·70—1·77	Yellowish-white translucent substance, of the consistence of wax, regular crystallised in octahedrons.	Readily inflammable, giving off phosphoric acid; forms acids with oxygen; may be distilled, and melts easily. Does not occur free in nature, plentifully, however, in combination with iron and nickel, in many meteoric stones, more frequently as an acid with different bases, as lime, alumina, magnesia, and the oxides of iron and copper; in apatite, wavellite, phosphates of lead, yellow arsenite, phosphate of copper, vivianite, triplite, etc.
11. Sulphur.	Sulphur.	S.	—	200·75	16	2·03	Yellow, crystallised in rhombic octahedrons, or in oblique rhombic prisms, translucent, friable.	Fuses readily, inflammable, volatile; burns with a blue flame, giving off sulphurous acid $S O_2$, with three equivalents of oxygen it forms sulphuric acid $S O_3$; is found pure in large quantities, in combination with the metals in the different glances and pyrites; also frequently in the blendes, as an acid with the bases lime, baryta, strontia, potass, soda, magnesia; in gypsum, anhydrite, heavy-spar, etc., with the oxides of the heavy metals, in the so-called vitriols, when of recent formation. Free sulphuric acid also occurs in springs of volcanic origin, sulphurous acid in the vapours of volcanoes, and sulphuretted hydrogen in many mineral springs (sulphureous springs).
12. Selenium.	Selenium.	Se.	—	494·58	40	4·3—4·32	Acicular or octahedral, friable, lustre metallic, lead-grey, translucent, with a red colour.	Becomes soft when heated, and melts; emits a dark yellow vapour, which diffuses an odour of decaying horse-radish, and forms a brownish red ring on the charcoal. Forms acids with oxygen and hydrogen. Is found in the seleniurets of sulphur, lead, mercury, silver, and in combination with copper and cobalt, in copper-lead seleniuret, and in cobalt-lead seleniuret; moreover, in many varieties of zinc-blende.

Name.		Symbol.	Electrical Relations.	Atomic Weight or Equivalent.		Specific Gravity.	Colour and Appearance.	FURTHER PROPERTIES AND MODES OF OCCURRENCE.
English.	Latin.			O = 100.	H = 1.			
13. Silicon.	Silicium.	Si.	—	277·31	21	2·490	Amorphous brown powder, or graphite like, lead-gray, hexagonal plates and lamellae, or regular octahedrons, with curved faces like the diamond. Forms alloys with other metals.	Is accordingly trimorphous, is fixed in the atmosphere, incombustible. Forms with oxygen silicic acid, and also, as it would appear, an oxide. Occurs always as pure silicic acid in quartz, very frequently in combination with different bases in the silicates. One of the most widely distributed bodies.

II. METALS.

A. Metals of the Earths.

14. Aluminum.	Aluminium.	Al.	+ —	171·16	13·7	2·56	Tin or silver-white, ductile, tolerably easily melted. Like silver, it retains its metallic lustre in the atmospheric air, and may be alloyed with other metals.	Occurs very frequently in combination with oxygen, and is distributed over the whole earth as alumina $Al_2 O_3$, native in corundum, with water in diaspore, gibbsite, hydrargillite, more frequently combined with the siliceous earths in the many silicates and the products of their decomposition, the clays and allophanes. Alumina also sometimes takes the place of magnesia and other monobases, with silicic acid, or of oxide of iron, as, for example, in spinel.
15. Yttrium.	Yttrium.	Y.	+ —	402·51	32·2	...	Unknown in a pure condition; as an oxide, yttria, it has until now been found associated with erbium and terbium under the name of gadolite, of sp. gr. 4·842.	Distributed sparingly in gadolinite, orthite, phosphate of yttrium, and the different combinations of cerium and tantalum.
16. Erbium.	Erbium.	Er.	...	...	...	...	*Vide* Yttrium.	
17. Terbium.	Terbium.	Tb.	...	...	...	...	Do.	
18. Glucinum.	Glycinium, or Beryllium.	G.	+	221·25	17·7	...	Dark grey, lustre metallic.	Is found as glucine, $G_2 O_3$, combined with silicic acid in the emerald, beryl, euclase, phenacite, with alumina in the chrysoberyl. It is soluble in potass, and with solution of cobalt does not give a blue colour before the blowpipe. The salts of glucina have a sweet taste, whence its name, which is derived from γλυκὺς (sweet).
19. Zirconium.	Zirconium.	Zr.	+ —	840·40	67·2	...	Coal-black, graphite-like powder, which, when polished, takes on a metallic lustre.	Takes fire in the heated air, and burns with a strong light into zirconia. Is found in zircon, malacon, eudialyte, æshcynite, œsterstedtile, wöhlerite, etc., sometimes with a little norium, generally in combination with silicic acid, or also with tantalic acid. Usually rare.
20. Norium.	Norium.	Nr.	...	...	...	...	Not yet at all known.	*Vide* Zircon.
21. Thorium.	Thorium.	Th.	...	744·90	59·5	...	Lead-grey heavy powder, which, on pressure, assumes a metallic lustre, and becomes tin-white.	Burns on being heated with evolution of flame to thorina, Th O. Is found sparingly in thorite, and orangite, in monacite, and Siberian pyrochlore, in combination with silicic acid..
22. Magnesium	Magnesium or Magnium.	Mg.	+	150·00	12	1·743	Tin-white crystalline granules of 3·0 hardness.	Burns when it becomes heated with a splendent white flame; is found at Magnesia, Mg O, in periclase, brucite, magnetite, meerschaum, and the various serpentine, augite, and hornblende silicates, combined with sulphuric acid in Epsom salts, and the so-called bitter (saline) springs, and as chloride of magnesium in sea-water, etc., pretty widely distributed.

B. Metals of the Alkalis.

23. Calcium.	Calcium.	Ca.	+	251·50	20	1·577	A beautiful yellow malleable metal, which remains bright in the dry atmosphere, and is oxidised in water.	Burns at 356° Fahr. with a yellowish flame, giving out sparks, and forms lime, Ca O. Is very frequently found in combination with carbonic acid in calcareous spar and limestone, in arragonite, dolomite, bitter-spar, etc., as sulphate of lime in gypsum and anhydrite, as silicate of lime in wollastonite, apophyllite, etc., as phosphate of lime in apatite, and a few other minerals, and is a very generally distributed element, especially of the earths, and also occurs in the vegetable and animal kingdoms.
24. Barium.	Barium.	Ba.	+	856·88	68·6	Heavier than sulphuric acid.	Silver-white, ductile.	Melts at a glowing red heat, and is not distillable; burns in the air. Forms an amalgam with mercury. Is found frequently in combination with sulphuric and carbonic acids, in heavy spar and witherite, tolerably frequently in baryto-calcite, harmotome and psilomelane, in general but rarely in double combinations.
25. Strontium.	Strontium.	Sr.	+	547·28	44	2·541	White.	When heated it burns with a yellowish white flame, and becomes copper-red when it is covered with oxide of strontium, Sr. O; fusible like calcium. Is found sparingly in strontianite and celestine, in stromnite, and bary-strontianite.

Name.		Symbol.	Electrical Relations.	Atomic Weight or Equivalent.		Specific Gravity.	Colour and Appearance.	FURTHER PROPERTIES AND MODES OF OCCURRENCE.
English.	Latin.			O = 100.	H = 1.			
26. Lithium.	Lithium.	L.	+	82.03	6·4	Lighter than naphtha.	Silver-white, tough, soft like lead, takes on a yellow tarnish in the air.	Melts at 275° Fahr.; may be drawn into threads; is oxidised in water without taking fire. Is set on fire by nitric acid. Occurs only in combination with silicic acid, phosphoric acid, and fluorine, in a few minerals, as petalite, spodumene, lepidolite, and the mica of Zinnwald and in triphylline. The carbonate is slightly soluble in water.
27. Sodium.	Sodium or Natrium.	Na.	+	290·90	23·2	0·972	Soft, plastic, silver-white.	Is oxidised in the air and in water without taking fire. It burns, however, as soon as it is heated with water, with a bright yellow flame, and the soda, Na O, is dissolved. The solution is strongly alkaline. Is found very plentifully in combination with chlorine in rock salt, bittern, and sea-water, also combined with carbonic acid in the natural soda, as a sulphate in glauberite, thenardite, etc., as borate of soda in borax and borocalcite, as nitrate of soda, combined with silicic acid in some felspars and zeolites. Is a frequent element in sea and shore plants, as well as in the animal frame.
8. Potassium.	Kalium.	Ka.	+	488·85	39·2	0·865	Silver-white, soft, pliable like wax.	Is oxidised in the atmosphere, and burns in water, and also when placed in heated air, with a violet flame, giving off oxide of potassium or potash, which being dissolved in the water, renders it highly alkaline. May be distilled. Is found in nitrate of potash, in sulphate of potash, more frequently in the felspars and felspathic minerals, and the clays and marls consisting thereof; moreover in many zeolites and micas, and generally in the ashes of plants, and to a small extent in animal bodies.
C. Heavy Metals or Metals Proper.								
29. Tellurium.	Tellurium.	Te.	—	802·12	64	6·257	Silver-white, friable, crystallises in rhombohedrons.	Melts easily like antimony, and is easily distilled; in heated air it burns with a bluish-green creeping flame, and diffuses a thick white smoke of telluric acid, Te O_3, with a peculiarly sour taste. Is found in small quantities in native tellurium, in graphic and black telluric ore, and in telluret of silver and telluret of bismuth.
30. Arsenic.	Arsenium.	As.	—	940·08	75·2	5·96	Greyish-white, rhombohedral, friable, volatile.	May be sublimed, evaporates on the heated charcoal, giving off a white smoke which smells like phosphorus or garlic, and is changed into arsenious acid, As O_3. Is found native as sulphuret of arsenic, arsenic pyrites, sulphur-arsenic pyrites, arsenical cobalt, arsenical nickel, arsenious acid, arsenical chalk, and the arsenical oxides of copper, iron, and lead; also in the grey copper ores and silver blendes.
1. Antimony.	Stibium.	Sb.	— +	1612·90	129	6·715	Bluish-white, friable, rhombohedral, hard.	Melts readily on charcoal, and gives off a white vapour of sesquioxide of antimony, Sb_2 O_3. Forms with other metals alloys, which are hard, but easily fusible. Is found native in small quantities, more frequently in combination with sulphur, in grey antimony glance, bournonite, zinkenite, jamesonite, red antimony glance, etc., also in the grey copper or fahl ores, in brittle glance silver, and red silver ore. It mineralises other metals, as sulphur and arsenic, and is found thus in antimonial silver, and nickel, and in nickel antimony glance. As an oxide it forms cervantite and sennarmontite, as antimonious acid it forms stiblite.
32. Molybdenum.	Molybdenum.	Mo.	— +	575·83	45·96	8·615	Tin-white, retains its metallic lustre in the air.	Difficult of fusion; burns in a strong heat, first to a brown, and then to a blue oxide, and finally to molybdic acid. Is found sparingly in nature as a sulphuret of molybdenum and molybdic oxide of lead.
33. Titanium.	Titanium.	Ti.	— +	303·68	25·2	...	Iron-grey powder, lustre metallic.	Burns in heated air with a strong flame, and emits sparks. Is found sparingly as the oxide in rutile, anatase, and brookite, in titanic iron, sphene, and in many clay iron ores, in the smelting of which it is given off in the metallic form as copper-coloured cubes which collect at the bottom of the furnace.
34. Tantalum or Columbium.	Tantalum.	Ta.	—	2312·5	185	...	Black powder, which, when polished, assumes a metallic lustre, or in dark grey masses.	Burns, in heated air to white columbic acid. Is found in tantalite, niobite, in pyrochlore, aeschynite, yttro-tantalite, and a few other rare minerals of this kind, frequently with niobium and pelopium, as Ta O_3, playing the part of an acid.
35. Niobium.	Niobium.	Nb.	—	1251·53	...	?	Unknown.	Only found as yet in the columbic minerals, and not yet fully described.
36. Pelopium.	Pelopium.	Pe.	—	?	?	...	Do.	Do. do.
37. Donarium.	Donarium.	D.	—	?	?	...	Do.	Until now only found in the orangite of Bergemann, and probably identical with thorium.
38. Tungsten.	Wolfranium.	W.	—	1187·50	95	17·6	Iron-grey, friable and hard, very difficult of fusion.	Retains its lustre in the air; in heated air it takes fire and burns to tungstic acid. Occurs sparingly, combined with oxygen only, in tungstic ochre and tungstic lime, as the deutoxide, W O_2, in combination with the protoxides of iron and manganese in wolfram ore, and as an acid in tungstate of lead.
39. Vanadium.	Vanadium.	V.	—	857·5	68·6	...	Silver-white, friable.	Burns at a glowing red heat, to the black oxide; dissolves in aqua regia with a dark blue colour. Occurs, but rarely, in vanadiate of lead and vanadiate of copper, also in some iron ores.
40. Chromium.	Chromium.	Cr.	— +	328·59	26·0	7·3	Iron-grey, friable, lustre metallic.	Difficult of fusion. Burns in the air to an oxide of chromium. Is soluble in hydrochloric acid, and in dilute sulphuric acid, with difficulty. Is not affected by nitric acid. Is found in chrome iron ore, in red lead ore, banquellinite, chrome iron, many serpentines and iron ores, and also in the emerald.
41. Uranium.	Uranium.	U.	+	2712·5	217	18·4	...	Burns in heated air with a bright flame to oxide of uranium; gives green solutions with sulphuric acid and hydrochloric acid. In pitch-blende it occurs as the protoxide, in uran-ochre and uran-bloom as the oxide and oxyhydrate, in uran-mica as the phosphate, in johannite as the sulphate of uranium.

Name.		Symbol.	Electrical Relations.	Atomic Weight or Equivalent.		Specific Gravity.	Colour and Appearance.	FURTHER PROPERTIES AND MODES OF OCCURRENCE.
English.	Latin.			O = 100.	H = 1.			
42. Cerium.	Cerium.	Ce.	+	575	46·0	...	...	In cerite, allanite, pyrorthite, fluoride of cerium, yttrocerite, monacite, mosandrite, tschefkinite, for the most part along with lantanium and didymium, and not as yet known in a pure state.
43. Lantanium.	Lantanium.	La.	+	...	...	...	...	*Vide* cerium, principally in lanthanite and monacite.
44. Didymium.	Didymium.	Di.	+	...	...	...	...	*Vide* cerium.
45. Aridium.	Aridium.	Ar.	+	?	?	...	Like iron.	Discovered by Ullgreen in the chromic iron ore of Röraus; perhaps a phosphatic or chromic iron.
46. Bismuth.	Bismuthum.	Bi.	+	1330·38	106·4	9·799	Tin-white to reddish, rhombohedral.	Easily fusible; is considerably extended on becoming solid; evaporates when heated, and leaves the charcoal tarnished yellow. Is found native, with sulphur mineralised in bismuth glance, bismuth silver, and needle ore, and telluret of bismuth; as oxide of bismuth in bismuth ochre, in combination with silicic and phosphoric acids in silicate of bismuth (bismuth blende).
47. Zinc.	Zincum.	Zn.	+	402·79	32·2	6·86 to 7·21	Bluish-white, rhombohedral, foliated.	Melts at 773°.6 Fahr.; is ductile between 212° and 302°; at a stronger heat it again becomes brittle, burns with a lively flame, and forms the white oxide. Oxidises slowly, and only superficially in the atmosphere. May be distilled; forms yellow alloys with copper. Occurs native; as a rarity contained in basalt; most frequently as calamine, smithsonite, zinc-blende, franklinite; also in galmite and red zinc ore, zinc bloom, and white vitriol.
48. Cadmium.	Cadmium.	Cd.	+	697·58	55·8	8·60 to 8·69	Almost silver-white, ductile, lustrous, easily reducible.	Is slowly oxidised in the open air, takes fire and burns with a brownish flame on being heated, and leaves a brownish deposit on the charcoal. More easily distilled than zinc. Is found sparingly as sulphuret of cadmium in greenockite, and renders many zinc ores impure, especially the blendes and calamines.
49. Tin.	Stannum.	Sn.	+ —	735·29	59	7·29	Almost silver-white, splendent, ductile.	Melts at 550°.4 Fahr., and evaporates at a higher temperature; leaves a white deposit on the charcoal; forms yellow alloys with copper. Is easily dissolved in most acids. Is found native sparingly, most frequently in tin-ore as an oxide of tin, in the pyrites combined with sulphur, and with silicic acid in stannine.
50. Lead.	Plumbum.	Pb.	+	1294·50	104	11·45	Bluish-grey, very soft and ductile, octahedral.	Melts at 611°.6 Fahr., evaporates and leaves a yellow deposit on the charcoal. Readily soluble in acids, with the exception of sulphuric acid, giving colourless solutions with them. Is found as sulphuret of lead in galena, bournonite, jamesonite, geocronite, etc., with selenium in the seleniurets of lead, of cobalt and lead, of mercury and lead, and of copper and lead; in an oxidised state it occurs very sparingly as minium, in white lead, lead-vitriol ores, in pyormorphite, green, yellow, red, and blue lead ores, in vanadiate, antimoniate, tungstate, and seleniuret of the oxide of lead.
51. Manganese.	Manganium.	Mn.	+ —	348·89	27·6	6·85 to 7·05	Iron grey, tough, hard.	In the open air it rapidly oxidises to a black powder; occurs with sulphur only in hauerite and manganese blendes; more frequently in an oxidised state, as the oxide, hydrate of the oxide, sesquioxide, and hyperoxide; also in helvine as the carbonate and silicate of manganese; is often distributed in nature with the iron ores, and forms one of the elements of the animal and vegetable kingdoms.
52. Iron.	Ferrum.	Fe.	+ —	350·53	27·2	7·6 to 7·84	Greyish-white, admits of being polished.	Preserves its lustre only in a perfectly dry atmosphere; in a quite pure condition is almost incapable of fusion; with a certain admixture of carbon it is however more readily melted; burns to the sesquioxide with emission of sparks, and is readily soluble in acids. Is found native in meteoric stones, and rarely as telluric iron; most frequently as the sesquioxide in magnetic iron ore, as the oxide in hematite, as a hydrate of the oxide in brown iron ore, as a carbonate of the protoxide in spathic iron ore, and sphæorsiderite; moreover, combined with phosphoric acid, arsenious acid, sulphuric acid, and silicic acid, in many minerals. As sulphuret of iron in pyrites and marcasite.
53. Cobalt.	Cobaltum.	Co.	+	369·00	29·5	...	Greyish-white passing into red, hard, to a small extent ductile, of granular fracture, somewhat magnetic.	Difficult of fusion; retains its lustre in the air; oxidises at a glowing heat; readily forms a solution of a red colour with nitric acid. The oxide gives a blue glass with the fluxes. Is found sparingly in combination with sulphur and arsenic, frequently also with nickel in cobalt glance and smaltine, in earthy cobalt, and in cobalt pyrites, etc., with arsenious acid in cobalt bloom.
54. Nickel.	Niccolum.	Ni.	+	369·67	29·6	8·3 to 9·118	Almost silver-white, strongly magnetic, readily reducible.	Becomes magnetic when heated, and is very difficult of fusion; is dissolved slowly by acids, most readily by nitric acid, with which it gives a green solution. With copper it forms white alloys. Is found chiefly combined with sulphur and arsenic, less frequently with antimony, in nickel ore, nickel glance, red and white arseniate of nickel; also in many cobalt ores, occasionally as nickel-ochre.
55. Copper.	Cuprum.	Cu.	+	395·69	31·8	8·921 to 8·952	Red, tough, ductile, and capable of being welded.	Retains its lustre for a long period in the atmosphere; is oxidised, however, in the fire, and in air containing carbonic acid, and becomes rapidly covered with verdigris. Is easily soluble in acids where air is admitted. The ores colour the flame of the blow-pipe green. Is found native, in combination with sulphur and oxygen, also frequently with acids in copper glance and chalcosine and chalco-pyrites, red copper ore, malachite, and lazurite, etc.

Name.		Symbol.	Electrical Relations.	Atomic Weight or Equivalent.		Specific Gravity.	Colour and Appearance.	FURTHER PROPERTIES AND MODES OF OCCURRENCE.
English.	Latin.			O = 100.	H = 1.			
56. Mercury or Quicksilver.	Hydrargyrum.	Hg.	+	1250·0	100	13·58 to 13·595	Volatile, solidifies at 40° Fahrenheit, and has then a specific gravity of 14·391, silver-white, octahedral.	Forms amalgams with silver and other metals, evaporates very readily, and is easily reduced. Is found native as an amalgam with silver and gold, as selenium-quicksilver, in cinnabar, and many fahl ores, in combination with sulphur.
57. Osmium.	Osmium.	Os.	— +	1244·21	99·6	10·0	Almost silver-white, or as a black powder.	Can neither be melted nor volatilised; it burns, however, in heated air to osmic acid of a strong smell; occurs but sparingly, and only in platinum and osm-iridium.
58 Iridium.	Iridium.	Ir.	+	1233·26	98·7	22·6	Almost silver-white, hard, octahedral.	Insoluble in aqua regia, strongly resisting fusion. Is found native, but always with platinum, osmium, rhodium, and rhuthenium, along with the native iridium; also found in osm-iridium and irite.
59. Ruthenium.	Ruthenium.	Ru.	+	652·00	52·16	8·6	Greyish-white, lustre metallic, friable, only somewhat fusible in oxyhydrogen flame.	Oxidises in the open air at a glowing heat, and forms bluish-black oxide, and is only slightly soluble in aqua regia. Is found in small quantities in the platinum ores, especially in osm-iridium.
60. Rhodium.	Rhodium.	Rh.	+	651·40	52·1	11·0	Almost silver-white, very hard and friable, very difficult of fusion.	Acted on by none of the acids; when alloyed with other metals, however, it is easily dissolved by aqua regia, and forms with it a fine rose-red solution. Is found only in small quantities in the platinum ores.
61. Silver.	Argentum.	Ag.	+	1349·66	108·1	10·50 to 10·566	Pure white, tarnishes in the air somewhat after a time, tough, ductile, regular.	Is readily soluble in nitric and sulphuric acids, and from the solution it can readily be precipitated by the addition of metallic copper. Is found principally native, and combined with sulphur, as in silver glance, black silver, most lead glances, red silver ore, and many fahl ores; also as the chloride, bromide, iodide, seleniuret, antimoniate, and telluret of silver.
62. Gold.	Aurum.	Au.	+ —	2458·33	199	19·33	Bright yellow, ductile to a high degree, splendent, and capable of polish, regular.	Melts at 2012° Fahr., and in its fused state presents a sea-green colour; when very thin leaves of it are seen by transmitted light, they have also this colour. Soluble only in aqua regia and chlorine. Is found only native or in combination with tellurium or mercury; also frequently in native silver.
63. Palladium.	Palladium.	Pd.	+	665·84	53·4	11·3 to 11·8	Almost silver-white, very difficult of fusion, but soft and malleable, regular and rhombohedral.	Is oxidised in the fire, and takes on a bluish tarnishing, but at higher temperatures becomes white again. Is soluble in nitric, hydrochloric, and sulphuric acids. Is found only sparingly native, also mixed with the metallic platinums.
64. Platinum.	Platinum.	Pt.	+	1233·26	98.7	21·3, when powdered 26.0	Almost silver-white, very difficult of fusion.	Soluble in aqua regia, and forms with it a brownish-yellow solution, which is precipitated by chloride of ammonia and salts of potash. It also forms the double chloride of ammonium and platinum when heated in the form of spongy platinum. Is found native, but always rendered impure by other platinum metals, and by iron. Gold also generally contains traces of platinum.

I. The Precious Stones or Gems.

I. THE PRECIOUS STONES OR GEMS.

The distinguishing peculiarities of these minerals are hardness (7—10°), density, transparency, lustre, and capability of polish, combined with beautiful, pure colours; they also generally possess a high specific gravity.

The elements of which they are composed are usually very simple: in the diamond pure carbon (C); in the ruby and sapphire pure alumina ($Al_2 O_3$), coloured by a little oxide of iron or manganese; in the emerald and beryl silicates of berylla, or glucina, and alumina; in spinel manganese and alumina; in the garnet silicate of alumina, oxides of iron, and manganese; in the topaz siliceous alumina, with aluminate of fluorine, and so on.

The colour of most precious stones is rather accidental than essential, since, with the exception of the garnet, they are all quite colourless when pure. They are, however, all highly valued and especially adapted for ornaments on account of their colour, lustre, and transparency. Others are used, on account of their hardness, for engraving and perforating soft stones, glass, etc., or as sockets for the pivots of watch wheels. Many can be split in certain directions, as, for instance the diamond in the four directions of the octahedral planes, the topaz and emerald in the direction of the straight terminal planes, and the planes of fracture in these appear to be distinctly foliated; in others, such as the garnet, splitting can be effected only very rarely, and the planes of fracture are irregularly crystalline. All those that may be split may also break in the same direction on being struck, or if allowed to fall.

The cutting of gems is effected by iron discs, at first by means of emery; in the case of the diamond, however, diamond-spar or corundite, and most frequently diamond dust, is employed for this purpose. The polishing is finally completed by using finely-prepared oxide of iron, ashes of tin, etc.

The artificial planes or facettes are always laid on as regularly as possible, in order to give the stone a form suitable to the purpose for which it is intended, and to produce the finest effect. The larger and purer the stone is, the more numerous are its facettes, and the price is also much increased. The value varies, moreover, with the size, the purity and brightness of the colours, in some cases in a simple, in others in a double and fourfold ratio. The setting of all fine stones is applied *à jour*, that is, without a base of metallic plate; less valuable stones are provided with such plates, and foil is usually employed for the purpose. Precious stones do not change on exposure to the air and light, but when set in rings and the like, they become gradually worn by friction, according to the degree of their hardness, so that the sharp angles and edges become somewhat rounded or dimmed. This is least observable in the case of the diamond; it is somewhat more marked in the ruby and sapphire, still more in the emerald and topaz, and in the chrysolite and garnet. They are not affected by water and the acids, and, with the exception of the garnet, are infusible before the blowpipe. A few of them change their colour at a white heat; the topaz, for example, becomes rose-red, and many garnets become black. The diamond at a very high temperature is wholly consumed, and changed into carbonic acid. This is most easily effected when in a powdered condition.

The price of the precious stones is regulated by their beauty, purity, colour, cutting, and size. It is calculated from their size, the standard being a carat, which is equal to $3\frac{1}{5}$ gr. Troy. The diamond is the most valuable, the rough carat of which is reckoned at £4: 10s.; when cut, larger stones cost about £9 to £12 per carat. Next to the diamond comes the ruby, emerald, sapphire, opal, and so on.

PLATE I.

FIG. 1-5 ROUGH, 6-9 CUT DIAMONDS.

We place the diamond in the highest rank among the precious stones, because it exceeds all others in hardness, lustre, and power of refracting rays of light, and it has in every age been the most highly valued. The diamond crystallises in the regular or monometric system. The primary form is an octahedron (Fig. 1), bounded by eight equal equilateral triangles. It is harder than the ruby (= 10°), and for this reason may be employed for scratching and perforating it, as well as all other hard stones and metals generally. The diamonds or splinters of diamonds, which are to be used for perforators or gravers, must, however, at least have one natural angle, because cut angles are much more easily worn down.

The specific gravity varies from 3·529-3·55, so that it is somewhat more than three and a half times heavier than water, and nearly of the same weight as topaz and spinel.

Colour is either entirely absent, or is inclined to a yellow, greenish, bluish, rose-red, or brown hue; there are also perfectly black varieties, which have been lately found for the first time, in large crystalline irregular grains, in Brazil. The most valuable are the white, rose-red, and bluish diamonds; the brown are least valuable.

In lustre and transparency, when either rough or cut, it exceeds all other precious stones, and is only approached by white-lead ore and lead-vitriol, and by the octahedral oxide of antimony. It refracts light very strongly, twice as strongly as glass, and on this account it may be used with advantage in the lenses of magnifying apparatus. It further has the peculiarity of dispersing the rays of light to a very high degree. For this reason, cut diamonds, especially brilliants, exhibit all the colours of the rainbow in play, a property only possessed by strong flint glass when mixed with oxide of lead, but not by the white topaz in similar circumstances. This peculiarity is in a smaller degree apparent in rose diamonds, and least of all in table diamonds.

The diamond is not affected by air, water, and other solvents, such as acids and salts of potash; it is, however, combustible in the focus of a large burning-glass and

in the oxyhydrogen flame, especially when it is reduced to powder. During the process, it first becomes opaque, then rounded at the angles and edges, and finally disappears. It then unites with two equivalents of oxygen, and forms carbonic acid, which disappears, proving that, like graphite, it consists of pure carbon. We recognise, therefore, in the diamond only one of the many elements of which the body of the earth consists, and that in the purest form, as a metalloid, like sulphur, iodine, and selenium.

The diamond was well known to the ancient Jews, Arabians, Greeks, and Romans, by whom it was obtained from India, where it occurs near Purstal, between Hyderabad and Masulipatam. There are other localities, Perma in Bundelcund, Ellora, and near Pontiana in Borneo. It is also found at Minas Geraes in Brazil, Bahia, Australia, Rutherford in North Carolina, the Urals, and at Constantine in North Africa. It is generally found loose in the sand, especially along with gold dust, as is shown in an example in the British Museum, which possesses a specimen of a crystal attached to alluvial gold. In Brazil it has been found in itacolumite or flexible sandstone, a stone composed of granular quartz and plates of mica.

It is obtained from the sand in several localities and in certain layers, by washing like gold.

Rough diamonds are for the most part crystallised and isolated, rarely worn to roundish, highly-lustrous grains The crystals usually present curved surfaces, striated in certain directions (Figs. 4 and 5), and are sometimes twins. They can all be split in the direction of the planes of the octahedron.

The cutting is effected by means of iron plates, with the help of powdered diamonds and a little water or oil.

They are for the most part small, and vary from the size of a millet seed to that of a pigeon's egg and larger, so that one even the size of a pea is a rarity.

The value varies with the purity of colour, transparency, and size, but not usually in a fixed ratio. A brilliant of one carat in weight costs eight guineas in England, one of two carats, of corresponding quality, is worth about 48 guineas; in those of twenty carats and upwards, the value increases at a higher ratio.

Cut diamonds are distinguished as—

1. *Table stones*, which more or less resemble Figs. 13 and 14, Plate II., bounded by rectangles, rhomboids, and trapeziums, flat on their upper and under surfaces.

2. *Rose diamonds* (v. Plate II. Figs. 14 and 15), flat below, curved above, and provided with six star-like triangular surfaces grouped together, which in larger stones are surrounded by twelve other similar facettes, sometimes they are irregular, oblong, etc., as is seen especially in old ornaments.

3. *Brilliants* of the form of an octagon, truncated above to a greater degree than on their under surface. The upper pyramid is called the crown or culasse, the lower the calette. The edges are so provided with rhombic faces and triangles, that the basal edges are sharpened, and the lateral edges facetted, as is distinctly seen in Fig. 6, Plate I. These are most highly valued, and show to the greatest advantage the above-mentioned play of colours.

4. *Round* or button-shaped stones, as is represented in Plate I. Figs. 7-9, were formerly cut only in large fragments, and for certain objects. The genuineness of the diamond is best ascertained from its hardness; it must be able to scratch the ruby and corundite, which neither the white topaz, nor still less flint-glass can do; the lustre and play of colours are also means of recognising it.

Figs. 10-16.—Corundite (Sapphire and Ruby).

The *corundite* is the hardest stone next to the diamond, and is scratched by it alone, while it can scratch all other stones, with the exception of the diamond. It consists, in its pure condition, of alumina only; coloured specimens contain traces of the oxides of iron and manganese, silica, and the like. The specific gravity varies from 3·9—140. We distinguish between noble and common corundum. To the former belong the ruby and sapphire, to the latter the diamond-spar and emery.

The form of the crystal is a rhombohedron, Fig. 10; there are, however, usually found combinations of the rhombohedron with hexagonal prisms, or these alone, as in Fig. 13, and also six-sided double pyramids.

The *ruby*, or deep-red corundite, Fig. 15, is the most valuable of all; it occurs of the finest quality in lower India and in Ceylon. The rough carat is valued at from £3 to £4. A ruby of two carats' weight, however, if perfect in colour and transparency, is more valuable than a diamond of the same weight, because it is much more rare. The *sapphire*, or blue corundite, Fig. 16, occurring from a clear to a dark blue, costs 30s. to 50s. and is also found in India, particularly in Ava, in Ceylon, Brazil, Bohemia and France, also at the Laacher-Sea, in Prussia.

The *diamond-spar* or *bort* is an impure corundite, which is used for polishing diamonds, and other precious stones; it comes from China, and costs from 20s. to 22s. a carat. The compact granular corundum is known by the name of *emery*, and is obtained chiefly from Naxos; it is, however, also found near Schwarzenberg in the Erzgebirge of Saxony, and is used for the cutting and polishing of glass, stones, etc.

Figs. 17-21.—Chrysoberyl (Cymophane, Alexandrite).

Right rhombic, in low prisms or tables, or in combinations of twins, with truncation of the acute or obtuse lateral edges, which form angles of 129° 38′. Hardness = 8·5, a little less than that of the corundum; specific gravity = 3·5—3·8.

Composition; alumina 78·91, glucina 18·02, oxide of iron 3·12, frequently with traces of the oxide of chromium.

Soluble in no acid, infusible before the blowpipe, gives with borax a greenish bead, from which salt of phosphorus does not separate silica. When polished, it is used as an ornament, and takes on a very fine polish. Yellow, green, and red; the yellowish-green, with play of golden lustre, is the most valuable. Is found in the primary formations, in granite, gneiss, and mica slate, in Moravia, Connecticut, and Siberia.

Figs. 22 and 23.—Spinel.

The primary form is a regular octagon, as seen in Fig. 22, and at the same time is of most frequent occurrence;

twin crystals are also found (Fig. 23) in aggregations of two half octahedrons. It is found white, red, blue, green, and black, highly lustrous, capable of polish, transparent, opaque, of 8° of hardness, and of a specific gravity from 3·5—3·8.

The constituent elements vary according to the colour and occurrence; there are magnesia, lime, iron, and zinc spinels; many of the Ceylon varieties contain some oxide of chrome, others silica. The usual formula = $\dot{R}\ddot{R}$, $\dot{R}$ representing magnesia, lime, oxide of zinc, and protoxide of iron, and $\ddot{R}$ alumina, and sometimes oxide of iron and chromium. Ulrich found in the red varieties of Ceylon, 26·21 magnesia, 0·71 protoxide of iron, 69·0 alumina, 1·10 oxide of chrome, and 2·02 silica. Insoluble in acids, infusible before the blowpipe, fusible with borax to a glass, from which salt of phosphorus generally separates some silica. The red varieties, on being heated, become brown and black; on cooling, however, they first assume a green, then a white, and at last again assume their original red colour. The black pleonaste gives a strong reaction of iron, the galmite or automolite, with borax, gives a schlag of zinc.

The deep-red spinel is called *spinel ruby*, the rose-red *balais*, the black *pleonaste* or *ceylonite*, the green *chlorospinel*, and that which contains zinc *automolite* or *galmite*. The two first rank as precious stones; they are, however, of less value than the oriental ruby, and are also inferior in hardness. They are found sometimes in the mud thrown up by rivers, as, for instance, in Ceylon; sometimes in volcanic remains, as at Auvergne, on the Rhine, in the Fassathal, at Vesuvius, rarely in granite and primary chalk, as at Aker in Sweden.

Figs. 24-27.—Zircon or Hyacinth.

Quadratic octahedron and prism, the octahedral planes placed either on the lateral planes (Fig. 24), or on the lateral edges (Fig. 25), or on the truncations of these (Fig. 26).

Colour; yellowish, reddish, brown, green, transparent to opaque. The transparent varieties are all valuable, and are used as ornaments under the name of oriental hyacinths, as seen in Fig. 27; they receive a magnificent polish. Hardness = 7·5, specific gravity = 4·4—4·5. Composition 1 of zircon to 1 of silicic acid = $\dddot{Z}r\ \dddot{S}i$, with traces of oxide of iron and lime.

Insoluble in acids, infusible, fusible along with borax to a greenish glass, from which salt of phosphorus separates silica in abundance. Is found in the granite of Miask, in the syenite of South Norway, in the volcanic minerals of Auvergne, and in the mud banks of Ceylon; here especially the yellow-brown hyacinth is found, which is worth from £4 to £6 a carat.

Figs. 28-33.—Beryl and Emerald.

Hexagonal prism (Fig. 28), with truncation of the basal edges (Fig. 29), or of the lateral edges (Fig. 30), or of both (Fig. 31). The yellowish-green (Figs. 28, 29), is called *beryl*, the bluish-green *aquamarine* (Figs. 30 and 33), the deep-green (Figs. 31, 32), *emerald*. Only the transparent varieties are considered as precious stones; the deep-green emerald is the most valuable, one carat being valued at from £2 : 10s. to £5; beryls, on the other hand, are cheaper than the topaz.

Hardness, 7·5—8·0; specific gravity, 2·68—2·73. Fusible in splinters; insoluble in acids. Composition, silicate of berylla (glucina), with silicate of alumina ($\ddot{B}e\ \ddot{S}i_2 + \ddot{A}l\ \ddot{S}i_2$); the colour is derived from a little oxide of iron and chromium, which are seen when melted with borax.

The emerald has smooth lateral planes; those of the beryl are situated in a longitudinal direction; on the other hand, the terminal planes of the emerald are dim or rough, while those of the beryl are mostly smooth. It is the lightest of all gems, properly so called.

The emerald is found in Egypt, where they were known to the ancients; in Peru, and in the limestone of Muzo in New Granada, of surpassing beauty and size; in the mica-slate of the Urals very large, but seldom quite pure, and at Salzburg; the beryl is found in Siberia, North America, in Silesia, and in the Bavarian forest near Zwiefel, at Limoges and Alençon in France.

PLATE II.

Figs. 1-7.—Topaz.

The *topaz* has for its primary form a right rhombic prism (Fig. 1); it is generally columnar, and striated vertically, and may be split in the direction of the even terminal planes. It has the eighth degree of hardness, and a specific gravity from 3·49—3·56. Like the diamond, it is highly lustrous, and receives a magnificent polish. The colour is white, vinous yellow (Fig. 2), brownish-yellow (Fig. 3), or sea-green (Fig. 4); the transparent varieties are known as *aquamarine*. The dark-yellow varieties, on being cautiously heated, become rose-red, and are then called *balais rubies*, a name which is also applied to the rose-red spinel.

The dark yellow (Fig. 6) are the most highly esteemed; they resemble the hyacinths so much as to be sometimes sold for them.

It is insoluble in acids, infusible before the blowpipe; with borax it forms a transparent glass, from which the silica may be separated by salt of phosphorus. The elements are—silicate of alumina, with fluoride of alumina ($3\ Al\ Fl^3 + 2\ Si\ Fl^3 + 6\ \ddot{A}l^3\ \ddot{S}i^2$).

It is found in the primary rocks of the Schneckenstein, near Auerbach, in Voigtland (Fig. 2), in Saxony and Bohemia, where it is mostly white, at Ekatherinenburg (Fig. 4), and also in the mud-banks of Brazil, in India, Asia Minor, etc. The transparent varieties are called *noble*, the opaque, *common* topazes; the latter, if they are widely separated from one another, as for instance at Altenberg and Schlakenwald, in the Erzgebirge, receive the name of *pycnite*, if they occur in a mass, as at Finbo and Braddo in Sweden, *pyrophysalite*. It is fusible in fine splinters. Only the pure white stones, especially those from Brazil, and the yellow and green ones, which are perfectly transparent and free from blemishes, are considered as precious stones.

Figs. 8-19.—The Garnet.

The Garnets belong to the most abundant, various, and finest of precious stones, although they certainly are but little valued on account of their frequency and cheapness.

The primary form is a rhombic dodecahedron (Fig. 8), which very frequently occurs without any further combinations. Besides this truncation of all the edges (Figs. 9 and 18), double truncation of the same (Fig. 11), and the trapezohedron (Figs. 10 and 17), also occur; they have no traces of the planes of the cube or octahedron, a circumstance which frequently serves to distinguish these stones from the vesuvian, which very much resembles them.

Hardness, 7—8; specific gravity 3·1—4·3. In acids it is either quite insoluble, or is only dissolved with great difficulty, silica being separated. The colours are brown-red, blood-red, deep-red, yellow, green, black, and white of all shades, transparent to opaque, highly lustrous to dim, capable of polish. The chemical constituents are silicic acid, with magnesia, calcium, protoxide of iron and alumina, oxides of iron manganese and chromium, $\ddot{R}^3 \overset{t}{\ddot{S}i} + \ddot{R}\,\ddot{S}i$.

The transparent finely coloured varieties are called *precious*, the others are called *common garnets;* they also receive different names from their colours. They are found principally in the slaty primary rocks of most countries, especially in the mica and blende slates, also in gneiss, more rarely in granite, or in volcanic rocks.

The red transparent garnets are the most highly valued, especially if they are large, such as the so-called *pyrope* of Bohemia (Figs. 13, 15), and the Indian amethyst coloured (Fig. 14), or the deep red *ruby garnet* (Fig. 19). The yellow ones (Fig. 16) are called *topazolites*, the apple-green (Fig. 17) *grossulars*, the deep-green (Fig. 12), *ouvarovites* or *uwarowites*.

Figs. 20-24.—The Vesuvian.

The *vesuvian* or *idocrase* has the same composition and fusibility as the garnet. It crystallises, however, in quadratic prisms, and always contains some water (1·7—3·1%); it also belongs by preference to the volcanic rocks.

Besides the simple tetragonal prism, with quadratic basal planes, truncations of the lateral edges (Fig. 20), of the basal edges (Fig. 21), and of the angles (Fig. 22), occur. The colour ranges between brownish-green (Fig. 23), grass-green (Fig. 22), olive-green (Fig. 21), and brown; the transparency also varies.

Hardness, 6—6·55; specific gravity, 3·0—3·4; when melted, it is always less (2·95).

It is soluble in hot acids, which separate the silica in the form of a jelly.

The elements are those of the garnet, in different relations, however, $= 3\dot{R}^3\,\ddot{S}i + 2\ddot{R}\,\ddot{S}i$, the basis of the first series being lime, magnesia, potass, or oxide of iron, that of the second alumina, oxide of manganese, iron.

Is found especially in Piedmont, in Norway, near Fiskum, also in the Fassathal, where the yellow-green varieties occur; at Eger in Bohemia, at Egg in Norway, etc.

The perfectly transparent green, or brownish green varieties, are sold as precious stones, under the name of *Vesuvian gems;* they are also called *Italian chrysolites*, or if they are brown, *hyacinths*; they may, however, be distinguished from the real stones of this name by their inferior hardness and lustre, as well as by their colour.

Figs. 25-27.—Chrysolite, Olivine.

The *chrysolite, olivine*, or *peridote*, belongs to a less used class of precious stones. It takes on a fine polish, however, and has an agreeable pistacio-green colour, which sometimes inclines to a yellow, a brown, or black; it is then called *common olivine;* and if brownish-black and rich in iron, it is called *iron-chrysolite* or *hyalosiderite*.

The primary form is a right rectangular prism (Fig. 25). This also occurs, however, combined with truncation of the lateral and basal edges (Fig. 26), so that the right terminal planes almost disappear, and the lateral planes are deeply striated vertically. More frequently it occurs in irregular grains or roundish masses, especially in basalt, which it characterises.

The precious chrysolite has the 7° of hardness; the common or iron-chrysolite the 5°. The specific gravity varies from 2·8—3·4.

The chemical constituents are silicate of magnesia, with silicate of the protoxide of iron ($10\,\dot{M}g^3\,\ddot{S}i + \dot{F}e^3\,\ddot{S}i$.).

Almost infusible, reducible in borax, however, to a green glass, from which salt of phosphorus separates silica.

The pure chrysolite occurs in the East, perhaps in Egypt, and is cut as stones for rings in the form of a table; the granular olivine of a yellow-blackish green colour occurs especially in the basalts, and, as is worthy of notice, in meteoric stones.

Figs. 28-30.—Epidote, Pistacite.

This mineral takes its place, from colour and appearance, with the two foregoing. It is, however, not usually employed as a precious stone, because it is rarely found transparent. The primary form is a right rhomboidal prism (Fig. 28); the lateral planes of which form angles of 115° 24′ and 64°.36′; the angles, basal and lateral edges also, are frequently truncated, so that very complicated forms frequently occur (Figs. 29, 30.)

The hardness = 6—7·0; specific gravity 3·26—3·42. Lustre, vitreous; the so-called *arendalite* is dark-green; the *thulite* is rose-red; the *manganesian epidote* of Piedmont is reddish-brown; the *zoisite* from the Fichtel-gebirge is grey or white. It can be split in the direction of the rhomboidal basal planes, and is friable; when translucent, however, it is capable of being polished. The elements are silicates of lime and magnesia, protoxide of iron with silicate of alumina, and the oxide of iron or manganese $= 2\dot{R}^3\,\ddot{S}i + \ddot{A}l\,(\ddot{F}e, \ddot{M}n)\,\ddot{S}i$.

Is found very frequently in large crystals; for example, at Arendal, in Norway, with calcareous spar, in the primary rocks, namely granite, syenite, serpentine, and mica slate; in Piedmont, Dauphiné, the Tyrol, near Auerbach, on the Bergstrasse, in Pennsylvania, on the Urals, &c.

Very difficult of fusion, with borax and soda it gives the colour of manganese and iron; insoluble in acids.

Figs. 31-34.—Turquoise, Calaite.

The *turquoise* is neither transparent nor very hard, and therefore without a trace of crystalline form or structure, yet it was formerly used as an ornamental stone, for which its beautiful colour renders it suitable.

It is found in irregular crust-like masses (Fig. 31), or as a shell over aluminous minerals (Fig. 32), and is prepared for cutting by sawing into peculiar roundish or square pieces. The fracture is even and dull, the colour verdigris to apple green (Fig. 32, 33), or bluish green (Fig. 34), the lustre is slight after polishing, porcellanous; the hardness = 6; the specific gravity = 2·86—3·0; the streak is white.

It is soluble in acids, infusible before the blowpipe, and with borax gives a feeble copper and iron reaction.

The constituent elements are phosphate of alumina, with water, which amounts to about 10 per cent. Formula $\ddot{Al}^4\ \ddot{P}^3 + 9\ \dot{H} + 2\ \ddot{Al}\ \dot{H}^3$.

The fine turquoises used as ornaments (Fig. 32-34) are found in the ferriferous siliceous schists at New Madan in Persia, the *calaite* or *johnite* (fig. 31) near Jordansmuhle in Silesia, also at Reichenbach and Planen in Voigtland.

Figs. 35, 36.—Lazurite or Lapis Lazuli.

This mineral crystallises in rhombic dodecahedrons (see Fig. 8 of this plate); it mostly occurs, however, in crystalline granular masses of varying capability of cleavage, of uneven fracture, and feeble vitreous lustre, but slightly translucent, sky-blue to a deep azure; the streak light blue. Hardness = 5·5; specific gravity, 2·5—2·9.

Chemical constitution—a combination of silicic acid, with alumina, lime, magnesia, and soda, and some sulphate of sodium or sulphate of iron.

The colour is destroyed by hydrochloric acid. White sulphuretted hydrogen is given off, and silicic acid is separated in the form of jelly.

Before the blowpipe flame it is tolerably easily fusible to a white glass, easily soluble in borax, leaving a little water on the charcoal.

It is found in gangues of granite and in granular chalk in Siberia, Thibet, China, and Bucharia, and was known to the ancients under the name of sapphire. When cut it is used as an ornament for mosaics and architectural decorations, boxes, vases, etc. Formerly it was principally used in the preparation of the valuable artists' colour, ultramarine, which is now, however, largely prepared by an artificial process.

PLATES III. AND IV.

Quartz, Silica, and Silicates.

These very frequent and widely-distributed minerals present an extraordinary diversity in form, colour, occurrence, and applicability. The crystallised varieties, if they are colourless, are called *rock crystals* (Figs. 4, 6, 7); if rose-red, *rose-quartz* (Fig. 3); if black or brown, *smoky topaz* (Fig. 4); if yellow, *citrine;* if violet, *amethyst* (Figs. 5, 8); if milky, cloudy *milky quartz;* if they are coloured red or yellow by oxide of iron, and non-transparent (Fig. 1), they are named *ferruginous quartz;* if they contain small acicular crystals of other coloured minerals, *needle quartz;* if they are opaque and colourless, *common quartz.*

The compact, non-transparent, and finely-coloured varieties, which are capable of taking on a polish, are called *jaspers, globulous jasper* (Figs. 9 and 10), if in rounded masses, and *riband jasper* if they are flat and striped. The dark green jaspers, studded with red spots, are called *heliotropes.* The translucent, fibrous, crystalline varieties, are called *chalcedony,* if they are of a single colour; the blood-red are *carnelians* (Fig. 14, and Plate IV., Fig. 2); those which are colourless, with arborescent figures in their interior, are named *moss agate* or *Mocha stone* (Fig. 15); the yellow are *riband agate* or *yellow chalcedony.* The single-coloured, compact, translucent, dark yellow, or grey quartz (Plate IV., Fig. 1), is called *flint;* if it presents a distinct grain, however, it is known as *horn-stone.* Many-coloured chalcedonies are generally called agates, and according to their different markings—*fortification agate* (Plate IV., Fig. 3), *cloudy agate* (Fig. 4), *ribbon agate* (Figs. 9, 10, 11, and 12); when different colours lie above one another, the stone is called *onyx* (Fig. 14), and if it is red and white, a *sard* or *sardonyx* (Fig. 13); *spotted agate* (Fig. 15), with red or brown spots appearing; *ruin* or *brecciated agate* (Fig. 16), if they appear to be composed of fragments, *variegated striped agate* (Fig. 17 and 18), if they are striped with different colours. The single-coloured apple-green chalcedonies (Fig. 8) are called *chrysoprase;* mottled quartz, composed of round masses, is called *pudding-stone* or *conglomerate* (Fig. 5).

Quartz, like the corundite and calcareous spar, has for its primary form the rhombic hexagon, which, however, does not occur by itself; on the contrary, the most usual form of the crystals is a hexagonal prism, combined with the hexagonal double pyramid (Plate III., Figs. 3 and 6), more rarely the pyramid (Fig. 1) occurs alone, more rarely still the rhombohedron occurs with the hexagonal prism or simple truncation of the six basal angles (Fig. 2).

The most interesting peculiarity of the rock crystals is, however, the great variety which arises from the different extensions of single planes or pairs of planes, for they are seldom so regular as those in Figs. 1-3. Already in Figs. 4 and 5 the pyramidal planes alone are present; in Fig. 6 these planes are very unequal, stretching downwards to a greater or less distance; in the group of crystals (Fig. 7) from Dauphiné, one terminal plane is principally extended at the expense of the others, and two of the six lateral planes are usually greater than the other four. Besides, simple or double, and one-sided truncation occurs at every three basal angles, the last is either on the right or left; further, there is simple and double truncation of the six basal edges, or of three of them only (Plate B, Fig. 6), which distinguishes a combination with other six, or three-sided pyramids.

The crystals sometimes reach the extraordinary size of two feet in breadth, by from three to six in length; but those large specimens which are found principally in the

high mountain ranges of Switzerland and Madagascar, are never quite pure and transparent.

The pyramidal or terminal planes are usually smooth and strongly lustrous, like glass; the lateral planes are more or less uneven, and striated transversely. The fracture is uneven, splintery, of a resinous lustre, but never vitreous.

The hardness is = 7, that is, it is harder than felspar, and softer than topaz. All the varieties of quartz give out bright sparks when struck against steel; in this process small fragments of steel are separated, burn, and melt into small nodules. It is not marked by a steel file; glass, however, scratches it easily. On a flat steel file it gives a shrill sharp sound. The specific gravity is = 2·65, the medium weight of all non-metallic minerals and stones, with the exception of the precious stones.

It is insoluble in water and acids; it is, however, attacked and dimmed by fluoric acid. With soda it can be melted, while by itself it is quite infusible even in the smallest splinters.

The chemical constituents of pure rock-crystal are pure silicates or silicas, oxide of silicon with three equivalents of oxygen = $Si\,O_3$ or $\ddot{S}i$. The bluish-reddish colour of the amethyst proceeds from oxide of manganese, the yellow of ferruginous quartz from the oxyhydrate of iron, the red from oxide of iron, the black smoky topaz from pitch or other carbonaceous elements; in short, all these colours are extra-essential or accidental.

The crystallised varieties of quartz occur principally in the primary mountains, and in the older stratified rocks, amethyst and agate in volcanic minerals and porphyry. The finest crystals are found in the Central Alps of Switzerland and in the south-east of France; beautiful single crystals, with both sides crystallised, occur in the Marmorosch and at Bergamo; the former have been called *Marmorosch diamonds*, because of their lustre. Fine specimens of rock-crystal are obtained in many parts of Cumberland, Cornwall, Devonshire, Gloucestershire (*Bristol diamonds*), and other localities in England and Ireland. In Scotland they occur particularly fine in the Grampians, and are well known as *Cairngorms*. These have a white, vinous-yellow, or fine brown colour, and are much valued as stones for ornament. Good crystals are also found on the Holy Loch, Argyleshire, at Leadhills, and in the Mull of Cantyre.

The compact quartz is found in layers in gneiss, mica schist, and granite; finely granular compact quartz is called quartz-rock, and it occurs in the older stratified rocks as well as in the primary formations. It is black and lamelliform, or in coarse slates; it is then called siliceous schist, and is used as a touchstone for testing the fineness of gold and silver. Quartz in granules is found imbedded in granite, gneiss, and micaceous schist, in the itacolumite of Brazil, and in many porphyries, as *sand* quartz occurs abundantly in the upper layers of the earth, in the tertiary, diluvial and alluvial rocks, and forms a great part of the sandy plains and wastes of Europe, Asia, Africa, America, and Australia. In many parts of the earth it contains gold, platinum, diamonds, and other precious stones. Sand forms an important element of the earth and soil, and bestows on it lightness, and affords the conditions which enable the roots of plants to imbibe it easily; it is especially useful to pines, and the esculent, tuberous, and bulbous roots. *Quartz sand* and pounded quartz are used in the manufacture of glass, porcelain, bricks, mortar, etc.; for white glass for mirrors, for optical instruments and porcelain, it must be perfectly pure and white. It is an important element of the *sandstones* which are found in most stratified formations, and frequently form extended mountain-ranges. The *fulgorites*, or *vitrified tubes* (Plate IV. Fig. 6), are formed by strokes of lightning in the sand, and are composed of melted grains of sand; they are frequently from four to six feet long, and divided into several branches They are found by shepherds in Northern Germany, in the Senner and Lüneburg heaths, and are generally somewhat blackened by *humus* or mould; externally they are rough, and internally vitreous and hollow. The *flints* are found in varying quantities in the white chalk, and in single layers of the Jura chalk, in roundish globules, sometimes in a tubular form, and sometimes as petrifactions of sea-urchins, mussels, snails, corals, etc. They were formerly used, when split into small square pieces, for striking lights in the hand, and also for the locks of fire-arms.

Compact quartz rock, granite rich in quartz, gneiss, and sandstone, are used in the formation of roads and pavements, for millstones, etc.

Perfectly clear rock-crystal, transparent smoky topaz, and unblemished amethyst, are used as ornamental stones cut into tabular and rosette shapes; the finest amethysts come from Brazil, Ceylon, and Siberia; very fine druces of amethysts are found at Schemnitz in Hungary, and in the globular jasper of Oberstein, sometimes also at Oppenau and Baden.

Chalcedony, agates of all kinds, carnelians, chrysoprase, and even many kinds of jasper, are used also as ornamental stones, and for all kinds of objects of art, as boxes, buttons, cups, lustres, etc. Chalcedonies of two colours, and onyx, are principally used for cameos, and gems, or cut-stones and signet-rings; the heliotropes and carnelians are used for rings also. This is, indeed, a time-honoured use, which was put in practice by the Egyptians, Greeks, and Romans, who, as the antique cameos bear witness, even in their time knew perfectly well the art of cutting these hard stones.

The finest chalcedonies come from India, Brazil, and the east, where they are found at Brussa, at the foot of Olympus; they occur, moreover, in Hungary, Silesia, Saxony, France, and in many other countries. At Blackdown, in England, very fine chalcedonies are found, as petrified snails and mussels.

The blood-red *carnelian* comes principally from Egypt, where it is found in the course of the Nile as far up as Nubia, in round nodules (Plate IV. Fig. 2), of all shades. The *sardonyx*, composed of rose-red and white, owes its agreeable colour to a layer, in which numerous red spots of oxide of iron are interspersed (Plate IV. Fig. 13); it must formerly have been particularly valued as a ring-stone, since the ring of Polycrates was made of it; it has also been found at Babylon. The *Arabian onyx* consists of black and white bands (Plate IV. Fig. 10), and was also very highly esteemed by the ancients.

Jasper is found for the most part in large masses in the igneous and stratified rocks; very fine brown nodular jasper, which receives a remarkably fine polish, showing most beautiful annular markings, is found in the course of the Nile (Plate III. Fig. 9). Red and yellow jasper (Fig.

10), is found in the pea-ironstone at Kandern and Auggen in the highlands of Baden, where it frequently contains a number of small snails. The ancients manufactured whole pillars of jasper for temples, altar-pieces, etc. In Russia, the ribbon-jasper (Plate III. Fig. 11), is still cut into all kinds of artistic objects. In Florence and Naples, all these stones together are employed in the manufacture of tables inlaid with the most beautiful flowers, leaf-work, and mosaic borders.

Pudding-stone, a kind of natural mosaic, composed of different-coloured nodules of quartz, held together by masses of quartz (Plate IV. Fig. 5), is found in England and Hungary, and is likewise employed in the arts.

Chrysoprase is a finely granular or compact quartz, coloured green by oxide of nickel, slightly translucent (Plate IV. Fig. 8), which, so far as we are aware, occurs only in the serpentine rocks at Kosemitz in Silesia, and is likewise used as an ornament.

PLATE IV.

Figs. 7, 19, 20.—Opal or Amorphous Quartz.

These minerals are distinguished by their irregular form, which is without any trace of crystalline shape or structure; by their flat or conchoidal vitreous fracture, small density and friability, and also by their small degree of hardness (= 5·5—6), and weight (= 2·0—2·2), compared with crystalline quartz. The chemical constituents are silica, with 3—10 per cent of water. It is also soluble in potash ley.

There are colourless transparent opals which are called glass or *water opals* (*hyalite*), coloured, variegated, translucent and clouded, dark coloured, and even black opals. The most valuable is the *noble opal* (Fig. 19), which is milky white, and exhibits a rich play of all the colours of the rainbow. This magnificent play of colours, combined with sparkling glimmer and lustre, cannot easily be represented in a plate. It is found in a porphyrytic mineral at Eperies and Czervenitza in Hungary; it is cut for ornament in a roundish form, and is very highly valued.

The *fire-opal*, almost transparent, and exhibiting a play of various colours, with yellowish flashes, occurs at Zimapan, San Miguel, in Mexico, also at the Azores, and at the Faroe Islands. Those from the first locality are most highly valued, and are also used as stones for ornament.

The *green opal* (Fig. 20) is found of remarkable beauty at Kosemitz in Silesia, and at Pernstein in Moravia. At these other places in Saxony, Bohemia, and Hungary, the common and so-called semi-opal are found in all colours and forms.

The *wood opal* (Fig. 7) is wood petrified by a mass of opal. The piece figured is a pine, with distinct concentric rings marking the age of the tree, and of perfectly opaline fracture, from Hungary. It is made into boxes, etc.

Besides these, silicic acid forms with the bases (earths and metallic oxides), many of the various combinations which in general are called *silicates*, as, for example, most precious stones, all felspars, zeolites, micas, clays, the minerals formed from or consisting of these; thus also the soils and earths contain much silica, from which it passes abundantly into the bodies of plants, and from these again into the animal frame. In the stems of the tree-like grasses (Bambusa) it forms itself into thick opal-like bulbs, which are known under the name of tabasheer.

PLATE V.

Figs. 1 and 2.—Cyanite or Disthene.

Cyanite takes its place among the precious stones from its hardness, appearance, and chemical composition; but, on account of its wanting the necessary purity, it can rarely be cut and used as an ornament.

The primary form is an oblique rhomboidal prism of 106° 50′ and 73° 45′; the inclination of the terminal planes towards the narrow lateral planes is 100° 50′ and 79° 10′; the lateral edges are in general truncated, as seen in Fig. 4, or there are two crystals aggregated as twins (Fig. 2). The fracture is uneven, the crystals may be split in the direction of the large lateral planes, and they are also curved.

Hardness = 6—7, specific gravity 3·55—3·67.

Generally light sky-blue to white, yellow, brown, or black; the latter varieties are called *rhætizite*, especially if they are radiatingly foliated; the streak is white.

Infusible and insoluble in acids, reducible to glass, however, with borax.

Elements: silicate of alumina = $\ddot{A}l_2\,\ddot{S}i$, with 68·994 of clay and 31·006 of silicic acid.

It is found frequently in the micaceous schists of the Gotthardt and the Tyrol, in Scotland, Pennsylvania, also in the gneiss and granite, as, for instance, in Pfitsch in the Tyrol, and at Breitenbronn in Saxony.

The fine blue transparent varieties are cut as stones for pins and rings. Very pure fragments, especially those from the East Indies, have been sold as sapphire; they may, however, easily be distinguished from these by their inferior degree of hardness.

Figs. 3-5.—Staurolite.

Staurolite is a mineral nearly related to the foregoing, of a dark or brownish-red colour, which crystallises in right rhombic prisms (Fig. 3). Truncations of the acute lateral edges (Fig. 4) and of the obtuse basal angles occur, and very frequently also twins joined in the form of a cross at right (Fig. 5) or oblique angles, or united perpendicularly to one another.

For the most part it is opaque or translucent, brownish-red, of the colour of common garnet.

Hardness 7—7·5; specific gravity 3·7—3·8.

Chemical elements: silicate of alumina, with aluminate of the oxide of iron ($3\,\ddot{A}l\,\ddot{S}i + \ddot{F}e\,\ddot{A}l^2$).

Insoluble in acids; slightly fusible by itself in small splinters; with borax it gives a green glass, in which oxide of iron is indicated; with salt of phosphorus silica is separated. It is frequently found with cyanite in the micaceous schist of the Gotthardt, and at Sterzing in the Tyrol, in the Pyrences, North America, New England, Chesterfield in Missouri, near New York, etc. Particularly fine twin crystals occur at Oporto and St. Jago di Compostella in Spain, also in Bretagne.

Figs. 6 and 7.—Andalusite.

Right rhombic prism, with slight displacement of the lateral planes at angles of 91° 33′ and 88° 27′; occasionally with truncation of the acute angles, as Fig. 6. Frequently in twins or quadruplets (Fig. 7), with clay-slate intervening, so that in a transverse section very fine cruciform figures are brought into view. Sometimes these crystals are hollow, and for this reason are named *hollow-spar* or *chiastolite*.

The colour is pearl-grey, reddish, or violet, the lustre slight, and it does not take on a particularly good polish. The fracture is unevenly splintered. Generally opaque or slightly translucent. Hardness = 7·5; specific gravity = 3·1.

Burns with a white flame before the blowpipe without being melted; insoluble in acids.

The chemical constitution is as follows: silicate of alumina ($\ddot{A}l^3\ \ddot{S}i^2$), sometimes with slight traces of chalk, magnesia, and oxide of iron.

It is found, especially in the primary rocks, at Lisens in the Tyrol, Penig in Saxony, Iglau in Moravia, Litchfield and Washington in Connecticut, Leiperville in Pennsylvania, Killiney Bay in Ireland. The hollow-spar occurs at St. Jago di Compostella in Spain, at Bayreuth in the Fichtel mountains, and in Cumberland.

Figs. 8-11.—Tourmaline, Electric or Rhombohedral Schorl.

The primary form is an obtuse rhombic hexagon, as seen in Fig. 9. They usually occur, however, as six, nine, and twelve-sided prisms, having their origin in the truncation of the basal edges and angles, as is seen, for example, in Figs. 8, 9, and 11. Sometimes three crystals are united twin-wise, like Fig. 10; truncation of the vertical angles (Fig. 10) and of the vertical edges (Fig. 11) also occurs. The lustre is lively vitreous; the lateral planes are mostly striated vertically; there are very long acicular crystals, and others very thick and almost as large as the hand. The colour varies much; there is black, green, blue, red, and even white tourmaline; transparent varieties are called noble or precious tourmaline; the opaque common tourmaline; those which are colourless are called *achroite* or *apyrite*, and the blue ones *indicolite*.

The hardness slightly exceeds that of the rock-crystal (7—7·5); the specific gravity is = 3·0—3·5. The fracture is uneven or conchoidal.

The elements are silicate of alumina, with borate and carbonate of magnesia, lithium, sodium, potass or protoxide of iron.

When heated, the long crystals especially acquire polar electricity, so that small bodies are attracted by one end and repelled by the other. For this reason it is sometimes called electrical schorl. Before the blowpipe small splinters melt into a brown or black slag; with borax the powder is fused into a clear glass, from which silica is extracted by salt of phosphorus.

It occurs principally in the primary rocks; granite containing tin, chlorite and micaceous schist are especially rich in specimens, as for example in the Tyrol and Norway. The green tourmaline is found in the dolomite near Campo Longo. Fine red and blue specimens occur in Brazil and Siberia. The finest and largest black tourmalines are from Greenland, and Modum in Norway; short black forms stamped with rhombohedrons, the so-called *aphricite*, are found imbedded in quartz at Bamle in South Norway.

Finely-coloured transparent tourmaline, when polished, are used as stones for ornaments; the red, blue, and green colours are most esteemed. Small stones of one carat weight cost from 6s. to 8s.; dark green of $6'''$ length by $4'''$ in breadth are worth £2 : 10s. to £3 : 10s. It may easily be distinguished from coloured glass by its hardness and electrical properties, while, on the other hand, it may be distinguished from the ruby, sapphire, and emerald by its lower degree of hardness and by the difference in colour.

Figs. 12 and 13.—Pelioma, Dichroite, Cordierite, Lynx-Sapphire, Water-Sapphire, Iolite.

Pelioma is generally found in six-sided prisms, with plane terminal faces, truncated in the basal edges, as seen in Fig. 12, sometimes also with further truncations, especially of the lateral edges; also of the basal angles, or in rounded granules and compact masses; the primary form, nevertheless, is a right rhombic prism of 120° and 60°, in the direction of which it may be split. The split surfaces are tolerably even, splintery and crystalline; this circumstance serves to distinguish it from quartz, which, however, possesses the resinous-like lustre; it has also the same, or even a less marked hardness (= 7—7·5). Its specific gravity is = 2·5—2·6.

When seen by transmitted light, the colour is bluish-brown or greyish-yellow, according as it is held in a perpendicular or horizontal direction; when cut, therefore, it usually exhibits a double play of colours, and for this reason it has been called lynx-sapphire; transparent fragments present double refraction of rays.

The composition is silicate of alumina and silicate of magnesia, and protoxide of iron.

In the blowpipe flame it melts when reduced to small fragments, and is readily distinguished from quartz. Pure transparent crystals are found principally in Ceylon and Brazil, and if they are of a fine blue, they are cut as stones for ornaments, especially for rings, under the name of *water-sapphire*. One of the size of Fig. 13 is valued at from 15s. to £1. There are also good crystals at Bodenmais in Bavaria, in Finland, Siberia, and Greenland; it occurs in a compact form at Twedestrand in Norway, and in North America. In Ceylon and Brazil it occurs in boulders.

II. HORNBLENDE AND AUGITIC MINERALS.

These are combinations of magnesia and of oxide of iron, with silicic acid, which resemble the foregoing minerals in hardness, are mostly dark green or blackish, and present a splintery fracture. They belong either to the primary or to the volcanic rocks, often colouring the latter grey or black.

FIGS. 14 and 15.—AUGITE, PYROXENE, DIOPSIDE, BAIKALITE, MALACOLITE, SAHLITE, COCCOLITE, VOLCANITE, BASALTINE, PYRGOME, FASSAITE.

Augite belongs to the series of hornblende minerals, from which it is less distinguished by its elements than by the difference of its crystalline angles, and its occurrence, in so far as it is principally found in volcanic formations. The primary form is an oblique rhombic prism of 87° 5′, and 92° 35′; the terminal planes are inclined to the sides at an angle of 100° 10′. The crystals may be split in the direction of the lateral and terminal planes, and of the truncated planes of the obtuse lateral edges.

The colour varies from black, through brown and green, to grey and white, hence the different names. The black and brown varieties are called common *augite*, the dark green *baikalite*, the light green and white *diopside*, the grey chalky varieties *malacolite* and *sahlite*, the small granular greenish and brown *pyrgome* and *fassaite*, and the compact foliated and granular varieties are called *coccolite*. *Uralite* is the name given to an augite from the Urals, which has the chemical composition of hornblende, and the crystalline form of augite.

The constituents are silicate of magnesia with silicate of lime, and the protoxide of manganese and iron.

The hardness is equal to 5·0—6·0; the specific gravity = 3·15—3·50. Before the blowpipe, it melts tolerably easily to a green or black glass. It is insoluble in acids. Very fine transparent crystals are found in Piedmont (Fig. 15), at the Lake Baikal in Siberia, and in the Zillerthal; the black varieties, the truncation of whose obtuse lateral edges and acute basal angles is represented in Fig. 14, occur principally in the volcanic rocks, as, for instance, in the Fassathal, at Vesuvius, in the neighbourhood of Rome, at the Kaiserstuhl, etc. They form an essential element of the basalts and dolomites, of most lavas, and of the augitic porphyry.

The transparent crystals from the Zillerthal are sometimes cut as stones for rings, and sold at about a couple of shillings each.

FIGS. 16-18.—HORNBLENDE, AMPHIBOLE, PARGASITE, KARINTHINE, ACTINOLITE OR STRAHLSTEIN, TREMOLITE OR GRAMMATITE, ASBESTUS.

Crystallises in oblique rhombic prisms of 124° 34′, and 55° 26′; the prisms, therefore, appear more decidedly rhomboidal than those of the augites, as a glance at Fig. 16, one of the usual forms of the so-called actinolites, will show. Truncation of the acute lateral edges and of the acute angles also occurs as in Fig. 17, which represents the so-called basaltic hornblende from Bohemia. It occurs, moreover, in crystalline fibrous, granular and compact masses. The long and finely fibrous varieties, like Fig. 18, are called *asbestus*; if the fibres are white, long, and delicate, *amianthus*, *earth-flax*, and *mountain-silk*; the varieties with confused and curved fibres, and which are light and porous, receive the name of *mountain-cork* and *mountain-leather*. The short and thick fibrous, white, grey and reddish varieties, if they feel sharp, and have a silky lustre, are called *tremolite*.

The hardness is = 5·0—6·0, the specific gravity = 2·9—3·2. The constituents are, silicate of magnesia, silicate of lime, and the protoxides of iron and manganese, but in proportions different from those of augite; sometimes a part of the silica is replaced by alumina.

Before the blowpipe, hornblende melts to a whitish or dark green glass; with salt of phosphorus, the splinters leave a skeleton of silica.

Hornblende forms an essential element of syenite, diorite, aphanite, greenstone, hornblende schist, hornblende rocks, and especially of the plutonic rocks; it is also found, however, in the matter thrown out by eruptions of Mount Vesuvius, and in many lavas, as, for example, in the so-called *breislakite*, a cupriferous acicular asbestus from Vesuvius and Etna.

As hornblende, especially if it is mixed with the rocks in thin layers and acicular forms, presents a marked curve, and is difficult of separation, it gives to these rocks a certain solidity, so that they are preferred to most kinds of stone for the construction of roads and pavements, sometimes also for monumental purposes; to this class belong the diorites and hornblende stones; the green porphyry (Plate VI. Fig. 6), which was formerly used by the ancients for the decoration of temples and palaces, owes its colour also to hornblende, as well as the black porphyry (Plate VI. Fig. 7).

Asbestus is applied to the manufacture of incombustible gloves and cloths; the varieties known under the names of mountain-silk or earth-flax, are found principally in the serpentine and micaceous schists of Switzerland and the Tyrolese Alps.

FIG. 19.—HYPERSTHENE, PAULITE.

The primary form is a right-rhombic prism of 98° 12′; it is found generally, however, only in crystalline foliated masses, from which fragments like Fig. 19 may be broken. The colour, between a greyish-black and copper-red, inclines also to brown and green. The hardness = 6·0, the specific gravity = 3·39—3·60. The constituents are the same as in augite, only that the protoxide of iron occurs in greater quantity. Very difficult of fusion, which can only be effected when it is reduced to the smallest possible splinters. This mineral is distinguished from hornblende by a certain metallic lustre, and, when cut, receives a good polish, so that it is sometimes used as a stone for ornament.

Fig. 20.—Wood-asbestus, Mountain-wood,

Has the look of common asbestus, of a still more brownish-yellow colour, splintery, with the appearance of half-rotten wood, and very light and soft; it has a meagre feeling, and adheres to the lips when wet. Hardness, 1·5—2·0. It has the same constitution as asbestus, with a quantity of water (about 10 per cent.), and gives, when heated in a test-tube, distinct drops of water. It occurs at Sterzing in the Tyrol.

Chrysotyl is distinguished from mountain-wood by its remarkable silky lustre and difficulty of fusion; it is, however, also a hydrous asbestus. It is principally found in delicate plates in serpentine in Moravia and Silesia.

Figs. 21—23.—Serpentine, Ophite, Steatite.

The crystals are right rectangular prisms, generally combined with truncation of the basal and lateral edges, as represented in Fig. 21, sometimes also with truncation of the basal angles. These, however, are considered as pseudomorphs, arising from the metamorphosis of olivine. More frequently serpentine occurs in compact masses, which form whole mountains, as, for instance, at Julier in Saxony and Silesia. The colour varies from yellow and green to brown, red, and black; the lustre is very slight, resinous; the fracture uneven; the hardness = 3; the specific gravity = 2·5—2·6. We distinguish between noble and common serpentines. The first are always somewhat translucent, of purer colour, and flat fracture; the latter are opaque, dark green to red, brown, and black, or variously mottled, as seen in Fig. 22. The constituents are silicate of magnesia with hydrate of magnesia. It is decomposed by acids.

Calcareous serpentine, *ophicalcite* or *brecciated serpentine* (Fig. 23), is a mixture of light and dark green serpentine and granular white chalk, sometimes aggregated with a small quantity of talc. It is found in Corsica and Upper Italy, and is applied to all kinds of ornaments, vases, pillars, tables, etc.; it takes on a fine polish.

The finest crystals of serpentine, as seen in Fig. 21, are found at Snarum in Norway, where the same mineral also occurs in compact masses of a wax-yellow colour, with talcose mica, and hydrous talcite.

The *common serpentine*, when it occurs in pure, unfissured masses, is used for altar-pieces, vases, pillars, etc., also for all kinds of small articles of household furniture, as mortars, candle-sticks, boxes, letter-presses, ink-stands, etc., of which there are manufactories in Saxony and Silesia. The degree of hardness being small, and not being friable, it is easily cut and dressed, and it also receives a respectable polish.

Fig. 24.—Schiller-stone, Eclogite, or Omphacite.

Schiller-spar or *diallagite* is a hornblende mineral, which occurs in green crystalline laminated granules, with oblique-angled fracture of the plates, very seldom by itself, but usually with garnet or a little granular quartz, as represented in Fig. 24. This stone has received the name of *omphacite* or *eclogite*, and is principally found at Hof and Gefrees in the Fichtel Mountains, at the Sau-Alps in Carinthia, and in Norway and other localities. In serpentine it is found at the Harz, in Saltzburg, and in Tuscany. The pure schiller-spar is splintery in fracture, of a vitreous to a metallic lustre, translucent, green to brown and blackish, difficultly fusible. It has a hardness of 3·5—4·0, and a specific gravity of 2·65—2·70. Bronzite, anthophyllite, and disterrite are allied hornblende minerals. The constituent elements are silicate of magnesia, with silicate of the protoxide of iron, and lime.

III. FELSPATHIC MINERALS.

These minerals play an important part in the mineral kingdom, in so far as they not only enter into it in the most varied forms, but they also constitute an essential element in the earth's crust, and by their decomposition under the influence of air and water, afford to the soil a constant supply of potass and soda salts, from which the vegetable world draws the alkaline salts necessary to the growth of plants. Further, there exist sometimes beds of clay and marl which, when mixed with sand and felspathic minerals, form an excellent soil for raising most vegetables. All felspars are combinations of siliceous clays and siliceous alkalis of crystalline structure, with obliquely angular foliated fracture. The hardness is = 6; they therefore, when struck with the steel, give off feeble sparks, and can only be scratched by a knife with great difficulty. Thus, too, they are but little friable, and impart to those rocks, the principal element of which they form, a certain solidity and durability. They contain no water; they take it up, however, and lose the freshness of their lustre in proportion as they are decomposed, while at the same time the alkaline elements are given off; this is the source of basic siliceous potash, soda, etc., and siliceous hydrate of alumina (clay). Before the blowpipe, fine splinters melt to a transparent, usually colourless bead, which, when wetted with a solution of cobalt, and heated anew, takes a fine blue colour. If held in the blue flame of the blowpipe by means of platinum forceps, the potash felspars colour the flame violet, the soda felspars colour it yellow, the lithium felspars purple-red, and the calcareous spars vermilion-red. In the mixed felspars, the yellow colour of the soda felspars generally preponderates. The specific gravity is between 2·50 and 2·76. The colour is accidental in them all, for in a pure state they are colourless; there are, however, red, green, and blackish-grey felspars.

PLATE VI.

Figs. 1—3.—Potash Felspar, Common Prismatic Felspar, Orthoclase Petrilite.

The primary form is an oblique rhombic prism of 118° 48′, as seen in Fig. 1; the crystals may be split in the direction of the terminal planes, and of the planes of truncation of the acute lateral edges, and less distinctly in the direction of the lateral planes.

Truncation of the obtuse angles, simple and double truncation of the lateral edges occur; also twins, quadruplets (as in Fig. 4, etc.), and very frequently compact masses or foliated granules. The hardness = 6·0, the specific gravity = 2·50—2·62. Transparent, translucent, opaque, sometimes with play of colours and iridescence. The lustre is externally vitreous, internally in the fracture pearly. The colourless transparent crystals, such as occur in the Zillerthal and at St. Gothard, are called *adular;* when polished, they occasionally present a peculiar splendour, and opalescent felspars are then called *moon-stones*, and if they contain red lustrous dots, *sun-stones*. The vitreous, transparent, fissured, and striated felspar, as it principally occurs in the trachyte of the Siebengebirge, at the Kaiserstuhl, Etna, etc., is called *sanidine;* on the other hand, those from the Laacher sea, in Prussia, and from the Somma, in which the silicate of soda preponderates, are called *rhyacolyte*, or *ice-spar*. The clouded apple-green variety (Fig. 2) from Labrador and from the Urals, is called *amazon-stone*, but if it is grey, milky-white or reddish, *common felspar*. The latter appears in thick masses of compact structure, and is called *compact felspar;* if it is granularly crystalline, it receives the name of *granulite*.

The chemical constituents are neutral silicate of alumina, and neutral silicate of potash, which are sometimes replaced by silicates of soda and lime. Thus, for example, the adular of St. Gothard, according to Abich, contains 17·97 of alumina, 13·99 of potash, 1·01 of soda, 1·34 of lime, and 65·69 of silica, the formula being $\dot{K}\,\ddot{S}i + \ddot{A}l\,\ddot{S}i^3$.

Before the blowpipe it melts in splinters into a somewhat blebby, glassy pearl, and colours the blue flame distinctly violet. Insoluble in acids. Dim and clouded felspars frequently contain 1—8 per cent of water.

The felspars are found principally in the primary rocks, and form an important constituent in granite, gneiss, syenite, diorite, and in most porphyries (Fig. 6—8); in the granites (Figs. 16 and 17) they generally appear in greyish-white and red granules of varying size and form; they are, however, easily distinguished by their peculiar crystalline fracture, their hardness, and ready fusibility from the resinous lustres of quartz, and the finely granular, almost metallic lustre of mica. Fine crystals are principally found in the clefts of transported primitive rocks; sometimes, however, also imbedded in granite; as, for instance, at Baveno, at the Fichtel-gebirge, at the Schwarzwald, in the neighbourhood of the Feldberg, in Bohemia, etc. Also in many porphyries, as in the Tyrol, at the foot of the Feldberg, opposite the Wiesenthal, in Sweden and in Greece. The glassy felspar is found in very fine crystals in some trachytes at Drachenfels, in the Sieben-gebirge, above Bonn.

The potash felspar serves chiefly as the ingredient which gives tenacity to masses of porcelain, and various enamels, and affords, by its decomposition, the purest porcelain (kaoline); as, for instance, at Aue, not far from Schneeberg in Saxony, at Limoges in France, and other localities. *Kaoline* is a fine triturable earthy substance, somewhat unctuous to the touch. It forms, with water, a kneadable mass, and at a white heat melts imperfectly, and becomes so hard as to give off sparks when struck by steel. The amazon-stone is polished for boxes and other small ornaments; the adulars are sometimes used as ornamental stones.

Fig. 5.—Soda-felspar, Albite, Pericline.

The primary form is an oblique rhomboidal prism of 120° 18′; it may be split in the direction of the terminal planes; less distinctly in that of the lateral planes. Truncations of the acute angles occur, and of the basal and lateral edges, especially in pericline, each by itself or with others, and very frequently twins, which can be recognised even in the fracture. The specific gravity of pericline is always somewhat under 2·60, that of albite is 2·61—2·62. The latter is always more or less transparent; the former, on the other hand, is of a milky-white colour. In reference to colour and lustre, all that has been said in reference to the potash felspars applies here also.

The chemical constitution is neutral silicate of soda and neutral silicate of alumina, combined in equal quantities ($\dot{N}a\,\ddot{S}i + \ddot{A}l\,\ddot{S}i^3$), a little lime or potash is, however, sometimes substituted for the soda. This is especially the case in the vitreous albites of many trachytic and dioritic porphyries, as, for example, in the so-called *andesine* from the Cordilleras. Insoluble in acids. Before the blowpipe, it melts somewhat more readily than potash felspar (4·0—4·5), and colours the flame distinctly yellow; if it contains a small proportion of lime, the flame has a reddish colour, the splinters give a somewhat blebby, transparent pearl.

The *Oligoclase*, or *Soda-spodumene*, of a specific gravity from 2·64—2·69, is also obliquely rhomboidal, of distinctly foliated fracture, and belongs to the series of soda-felspars containing lime and potash. It is found of a yellow-green at Bodenmais in Southern Norway, and at Stockholm.

The soda felspars form an element of many granites, porphyries, syenites and trachytes, also of many old lavas and clink-stones.

Figs. 6—8.—Porphyry.

Those volcanic rocks are so called which inclose in a primary homogeneous mass crystalline grains of felspar, quartz, and the like, and principally enter into the composition of the primary, or older stratified rocks, as filling up crevices, in layers or eruptive masses. Those are called *felspar porphyries*, the primary mass of which is formed by compact felspar, and as these are, for the most part, coloured, we again distinguish between green (Fig. 6), black or brown (Fig. 7), and red (Fig. 8) porphyries.

The latter are the most important, and are found of remarkable beauty in Upper Egypt (Fig. 8); they were formerly, by the ancient Egyptians, frequently used for monumental pillars and buildings, and even for statues and sarcophagi, and serve for similar purposes to this day. Particularly large crystals are found in the southern Tyrol; red porphyry is, however, widely distributed in the Schwarzwald, the Erzgebirge, in the Bogese, and in the Caucasus. It furnishes an excellent material for the construction of roads and pavements. The green porphyry appears principally in the transition rocks, as, for example, in Norway; it derives its colour from green hornblende, and is frequently changed by diminution of the felspathic granules into common *diorite* and *greenstone*, and if it loses its granular structure, into *aphanite*. The finest antique green porphyry (Fig. 6) is obtained from Greece; it receives a magnificent polish, aud is used for artistic purposes, for the decoration of churches and palaces. The brown and black porphyry (Fig. 7), which derives its colour from black hornblende, is found of the finest quality at Elfdal in Sweden, where it is used in a similar manner.

Figs. 9 and 10.—Labrador Felspar, Calcareous Felspar, Labradorite.

This mineral likewise crystallises in oblique rhomboidal prisms of 94° and 86°, and admits of cleavage in the direction of the basal planes; the splintered fragments present on two sides a remarkable parallel striation, and exhibit in another direction play of colours from grey to green, yellow, and red (Figs. 9 and 10). The planes of cleavage are remarkably uneven, splintery, and of resinous lustre. The hardness is = 6°, the specific gravity 2·68—2·76; the calcareous felspars are, therefore, the heaviest of all. The chemical constitution of real Labrador felspar from the Labrador coast is—silicate of lime with silicate of soda to two equivalents of tri-silicate of alumina. $\dot{C}a^3$ ($\dot{N}a^3$) $\ddot{S}i^2$ + 4 $\ddot{A}l$ $\ddot{S}i$. It is decomposed by concentrated acids, and the silica is separated. Before the blowpipe it melts like potash felspar; it imparts to the flame, however, a remarkable yellow-red colour, especially if the test be dipped in oil or tallow. The finest felspar, with iridescent play of colours, as in the two examples figured, comes from the island of St. Paul's, and from the mainland of Labrador, in large partially rounded fragments. It is found, however, in Finland and in the syenite of Saxony, in many dolerites, in the gabbro and hypersthene rocks, but without play of colours. It is used, when polished, for boxes, stones for rings, brooches, etc.

The *anorthite*, a felspar from Vesuvius, crystallises in similar, but more distinctly marked oblique rhomboidal prisms of 110° 57′ and 69° 3′, and presents a remarkably vitreous lustre. It also contains, in addition to silicate of lime, silicate of magnesia, and a little potash, but it is decomposed by acids, and is found principally in the remains of Vesuvius, and at the Somma.

The *petalite* is a klino-rhomboidal or triclinic, and the *triphane* or *common spodumen*, a klino-rhombic or monoclinic lithium felspar, both of which, before the blowpipe, distinctly give the purple red colour of lithium, and melt somewhat more readily than the other felspars. The former is colourless and of vitreous lustre, the latter is greenish and translucent. Found at Sterzing in the Tyrol, near Dublin, and in other localities.

IV. MICACEOUS MINERALS.

These are distinguished by their low degree of hardness (1·0—2·5), by a remarkable cleavage in thin plates in one direction, and by pearly metallic lustre. The thin plates have a strong play of colours, are flexible, sometimes elastic, and difficult to break, hence they impart to rocks a certain firmness and toughness, and an arrangement of schistic structure, so that they mostly form peculiar schistic rocks, such as gneiss, mica-slate, talc, and chlorite schists.

All of them are more or less easily fusible before the blowpipe; they also agree with the felspathic minerals in relation to their composition, so far as they are combinations of silicate of alumina with the monobasic silicates, potash, soda, lithium, magnesia, protoxide of iron, etc. In general, they owe their colour to the silicate of the protoxide or oxide of iron and manganese.

Fig. 11.—Pennine, Rhombohedral Mica.

Pennine crystallises in acute rhombohedrons, sometimes with truncation of the vertex, as seen in Fig. 11; the crystals can be split, in the direction of their basal planes, into very fine flexible laminæ; it is also found in foliated masses. The colour is green or yellowish-brown, inclined to black; fine plates of it are transparent. The hardness, is greater than that of chlorite and talc, and exactly the same as in mica (= 2·5), the specific gravity is 2·62—2·64. The constitutents are silicate of alumina, with silicate of magnesia and protoxide of iron, and 12·58 of water, the formula being—

$$\left.\begin{matrix}\dot{M}g^3\\ \dot{F}e^3\end{matrix}\right\}\ddot{S}i^2 + \ddot{A}l\ \ddot{S}i^2 + 7\ \dot{M}g\ \dot{H}.$$

It is therefore a hydrous magnesian mica, which in a heated test-tube gives off water; before the blowpipe it melts to a blackish bead without colouring the flame. It is found in remarkable quantity in the neighbourhood of Wallis, near Zermatt, at Zinnelgletscher, and at several places in the Tyrol.

Figs. 12 and 13.—Common Mica, Lithium and Potash Mica, Biaxial Mica, Muscovy Glass, Cat's Silver and Cat's Gold, Muscovite Mica.

The primary form is an oblique rhombic prism of 60° and 120°, the directions of the plates or laminæ are only parallel to the basal planes; six-sided tables (Fig. 13) are,

however, frequently found, with equal angles of 120°, as, for instance, at Vesuvius, in many granites, etc. The laminæ present in reflected light a strong pearly-metallic lustre, by transmitted light the lustre is vitreous; they are very flexible and very elastic, a characteristic of no other mineral. They do not show any traces of further lamination. It is otherwise where the mineral breaks into foliated masses (Fig. 12), where a separation into oblique rhombic tables cannot be mistaken. The hardness is equal to 2·0—2·5, so that it can be scratched by the nail; by this circumstance mica may be essentially distinguished from talc and chlorite, and, besides, it has no greasy feeling to the touch. Before the blowpipe it melts only at the edges to a more or less coloured glass, and colours the flame a pale violet.

The lithium micas, to which belong the silver-white varieties of Schlackenwald and Zinnwald, as well as the red and green lepidolites of Moravia, resemble the common mica in the form of their crystals; they are distinguished, however, by their easy fusibility, and while being melted, they swell up and colour the flame purple-red. They contain always a little fluorine, and on this account always experience a sensible loss at a white heat.

The constituents are, in general, silicate of alumina and oxide of iron, with silicate of potash or lithia; $\dot{K}\,\ddot{S}i + 4\,\ddot{A}l\,(\ddot{F}e)\,\ddot{S}i$ with which there occasionally occurs a little water, and in the case of lepidolite, fluorine and lithia. Not decomposed by acids. In the atmosphere it gradually exfoliates, and by exposure to water it becomes at last dim and friable.

Mica forms an important constituent of granite, gneiss, mica-schists and many porphyries; it is also found amongst the products of volcanoes, and in many of the older lavas. In many granites it occurs in tables from an inch to a foot in size; as, for instance, at Aschaffenburg in South Norway, at the Urals, etc.; it is, however, generally disseminated in metallic-lustrous laminæ, sometimes radiated, or in nodules, as *plumose mica*. The colour is either silver-white, pinchbeck brown, or black, more rarely bright yellow or rose-red, and is usually added to the names. The specific gravity varies from 2·7—3·0, according as it contains oxide of iron or of manganese, which can easily be determined before the blowpipe with borax and soda. The *rose-red lepidolite* is found especially at Rozna in Moravia, where it occurs in compact crystalline and foliated masses; the green variety is also found at the same place.

The *uniaxial mica* (volcanic or magnesia mica), has a rhombic hexahedron for its primary form, and is therefore also known as rhombohedral or hexagonal mica. It occurs usually in hexagonal tables, is a little more easy to split, somewhat more friable, and of a more vitreous lustre than the former, and presents, in polarised light, a single ring of colours, while the other presents two. The best marked crystals are found at Vesuvius, sometimes of a green, and sometimes of a black colour; it occurs in foliated masses in Greenland, Labrador, Siberia; also at Bodenmais in Bavaria, and at several places in North America. The chemical constituents differ in so far as the magnesia plays the principal part, after the oxide of iron, among the basic elements.

In the green mica of the Zillerthal, which has been called *fuchsite*, a certain amount of oxide of chrome appears in addition to the silicates of iron and magnesia.

The application of mica is limited to optical experiments and window panes. On account of the ease with which it may be split, and its transparency, it is also used for putting up physiological and anatomical preparations from the vegetable and animal kingdom for microscopical observations.

Fig. 14.—Chlorite, Ripidolite.

Crystallises in right rhombic prisms of 120°, or in hexagonal prisms and pyramids.

Presents a distinctly foliated structure in the direction of the terminal planes, slight hardness (1·0—1·5), and a specific gravity of 2·65—2·8; has a slightly greasy feeling, is flexible but not elastic, and in appearance sometimes approaches mica, sometimes talc. Most frequently it is found in scaly foliated masses of a leek-green to a dark-green colour, as in the chlorite schist of frequent occurrence in the Alps, especially in the Zillerthal and in Piedmont. The variety described under the name of *ripidolite* by Kobell, which is principally found in Dauphinée and Piedmont, crystallises in low hexagonal double pyramids (Fig. 14), which sometimes appear transparent and dichroate, green and yellow, or hyacinth red; sometimes also it occurs in curved aggregations of leaves like talc, as in Fig. 15.

Fig. 15.—Talc, Prismatic Talcose-mica.

Crystallises likewise in rhombohedrons, sometimes in small hexagonal tables, which are of foliated structure and biaxial. It feels soft and highly greasy to the touch; like no other mineral, it may be torn out in thin plates, which are very flexible, and may be easily scratched by the nail.

It occurs sometimes in worm-like curved foliated aggregations, which form hexagonal prisms, as in Fig. 15. Externally, it can only with difficulty be distinguished from chlorite, but much more easily with the help of the blowpipe; for here, as it contains no alumina, but consists only of silicate of magnesia and water, it gives, when melted in fine laminæ, wetted with a solution of cobalt, and heated, not a blue, but a rose-red colour. It occurs sometimes in very dense masses, almost compact, in fibrous-foliated, and in scaly earthy forms; it also constitutes the rock known, especially in the Alps, as talcose slate, and pot-stone. Formula, $\dot{M}g^{6}\,\ddot{S}i^{5} + 2\,\dot{H}$.

The *pyrophyllite*, or *radiated talc*, on the other hand, which from its appearance, flexibility, slight degree of hardness, pearly lustre, etc., has the greatest resemblance to talc, contains a considerable quantity of alumina, with very little magnesia. It is found at Beresowsk in Siberia, and Salme-Château in Belgium.

The scaly talc is used like graphite for the lubrication of machinery in order to lessen friction; also for polishing alabaster, and varnishing leather; and if it is perfectly white, as a white paint for the face.

Figs. 16, 17.—Granite.

Before leaving the felspathic and micaceous minerals,

we must glance at the granites which are so widely distributed in the primary rocks; the more so because they are so frequently the sites of other crystallised minerals, already described, as well as of the following ores.—*Granite* is a crystallised granular mixture of felspar, quartz, and mica, in which these elements lie, without definite order, in cross and transverse aggregations, so arranged, however, that externally, the crystallised planes of any of them are seldom apparent. The individual elements are more easily distinguished by their peculiar structure and lustre, and by their colour and hardness; felspar, in general the principal element, is recognised by its even, crystalline-ladderlike fracture, being difficult to scratch with the knife, giving pale sparks with the steel, having sometimes a greyish-white, sometimes a reddish (as in Fig. 16), and sometimes a brownish-red colour (as in Fig. 17); quartz is usually only disseminated in small irregular grains of resinous lustre and uneven fracture, not capable of being scratched by the knife, giving bright sparks with the steel, and infusible before the blowpipe; mica, sometimes silver-white, sometimes black (Figs. 16, 17), of a remarkable foliated structure, strong metallic or pearly lustre, of little hardness, and extraordinary elasticity of the laminae. Granite is not easily decomposed, very solid and hard, and is found from the smallest grains to medium and coarsely granular, so that the mica and felspar especially, sometimes attain the size of several square inches, and stand out from the granite, as, for example, in the silver-white mica figured in the plate (Fig. 12), from Modum in Sweden. Granite belongs to the most widely-distributed rocks of the primary formation, and sometimes rises to the highest mountains; it forms broad mountain ranges; it appears, however, sometimes in gangues, apparently breaking through the slaty rocks, or issuing out of the older stratified rocks. This occurs especially in many valleys, and is more fully discussed separately in treatises on geology. It was used, on account of its durability and beauty, by the ancients principally for monumental purposes, such as monolithic obelisks, sarcophagi, vases, etc. The granite of Baveno (Fig. 16) is still applied to small works of art, and takes on a very fine polish. The red granite of Upper Egypt (Fig. 17) was formerly used by the ancient Egyptians in the construction of their temples and pyramids, and especially for their numerous sepulchres, for sarcophagi, and was even worked into statues.

V. ZEOLITIC MINERALS.

These essentially resemble in their elements the felspars, in so far as they generally occur in a crystalline or crystallised form, and, with the exception of the leucite, are combinations of silicic acid with alumina and the alkalis. They may be distinguished from them, however, by their considerable percentage of water, and by their ready fusibility, which is such that they can be decomposed by acids. In general they are colourless, or only accidentally coloured, and appear principally in volcanic rocks, sometimes in their clefts or cavities, sometimes mixed with them or forming the greatest part of their bulk; so that, by the crumbling of the rocks concerned, they exercise the same influence on the vegetable world as the felspars. The combinations of soda and lime, however, play the principal part among the alkaline elements, and potash only enters as an important element into the leucite.

PLATE VII.

FIG. 1.—LEUCITE, WHITE GARNET, AMPHIGENE.

The *leucite* crystallises almost always in a trapezoidal solid with four-and-twenty faces, which body is for this reason also called a leucitoid; the cube with truncated angles has also been observed, however, and therefore some specimens have the primary form of the cube; irregular and roundish grains are more frequent. The crystalline faces appear generally dim or but slightly lustrous, sometimes they are rough, or of grey, yellowish, and reddish colours. The fracture is extremely irregular, vitreous, lustrous, and conchoidal, according as the mineral has been submitted to a white heat or to melting; the planes are also seldom in proportion to one another, sometimes several crystals are aggregated in a drusy form, or twin-wise. The hardness is 6·0—6·5, so that it gives sparks with a steel, but on being struck it generally flies in pieces, indicating its vitreous friability. It is decomposed by hot acids, and the silica is separated. The powder has an alkaline reaction, and colours a decoction of violets green, by which it may easily be distinguished from all other similar minerals, and especially from the felspars. The constituents are two-thirds of silicate of potash with three equivalents of silicate of alumina $\dot{K}^3\ \ddot{S}i^2 + 3\ \ddot{A}l\ \ddot{S}i^2$. Infusible before the blowpipe, but colouring the flame distinctly blue. It forms an important ingredient of the older lavas of the Somma and of Vesuvius, at the Laacher Lake, and in the neighbourhood of Rome.

FIGS. 2 AND 3.—ZEOLITE, MESOTYPE, NATROLITE.

Zeolite crystallises in right rhombic prisms of 91° 20′ and 88° 40′ as its primary form; in such a way, however, that usually the basal edges are truncated, and form the combination with the rhombic octahedron (Fig. 3); more frequently it occurs in fascicular needles, which are transparent and colourless. Hardness = 5·0—5·5, specific gravity = 2·2—2·25. The *natrolite* (Fig. 2) appears in semi-globular, kidney-shaped forms, of concentrically radiated structure, of yellow, reddish, brown, and white colours, so that, in a transverse section, or when polished for ornamental purposes, it presents star-like markings; sometimes also it occurs in crystalline aggregations, white, rose-red, fleshy-red, or brown, with a pearly or silky lustre. The constituents are silicate of soda and silicate of alumina, with

two equivalents of water, $\dot{N}a\ \ddot{S}i + \ddot{A}l\ \ddot{S}i + 2\ \dot{H}$. The yellow and red-coloured varieties always contain a small quantity of oxide of iron. Fine needles melt readily in a flame to small globules, and still more readily before the blowpipe into blebby pearls, and give off water; with greater difficulty they can be melted into a white glass. They colour the flame always yellow, and with salt and phosphorus they leave a skeleton of silica. *Scolezite*, which occurs in the Faröes and in Iceland, contains, instead of the silicate of soda, silicate of lime, and reddens the flame. There exists, however, a soda and lime zeolite, which has been called *mesolite*. The finest natrolites are found in crystals in Auvergne and in Bohemia, in radiated bundles in Iceland and the Faröes, the radiated natrolite occurs in clefts of the clink-stone at Hohentwiel, Mägdeberg, and Hohenkräken in the Högau; that from the latter locality has been polished as marble. Natrolite especially is an essential ingredient in clink-stone.

Fig. 4.—Heulandite, or Oblique Rhombic Foliated Zeolite.

The primary form is an oblique rectangular prism, and occasionally right rhomboidal and oblique rhombic prisms occur, with different truncations of the edges and angles, as, for example, in Fig. 4, in which the acute basal and lateral edges of the monoclinic prism are truncated. The crystals are easily split in the direction of the rhomboidal planes, and present a remarkable foliated structure; they are transparent to opaque, of vitreous or pearly lustre, generally colourless, reddish to tile-red, friable, moderately hard (3·5—4), of 2·2—2·3 specific gravity, soluble in acids. The ingredients are silicate of lime with silicate of alumina and water. Formula $\dot{C}a\ \ddot{S}i + 4\ \ddot{A}l\ \ddot{S}i^3 + 18\ \dot{H}$. Fuses before the blowpipe with intumescence to a white enamel, and colours the flame a yellow-red. On charcoal it gives off much water. This mineral is frequently confounded with stilbite, to which it bears some resemblance in appearance, hardness, lustre, and chemical constitution, and deportment before the blowpipe; it may be easily distinguished from it, however, by the form of the crystal, since stilbite belongs to the right rhombic system. It occurs principally in amygdaloid and diorite, as, for example, in the Fassathal (here it is tile-red) in Bohemia, in the Faröes, and Iceland; it is also found, however, in gneiss and mica in the United States, at Kongsberg in Norway, and in the clay-slate at Andreasberg.

Fig. 5.—Stilbite, Foliated Zeolite, Desmin.

The primary form is a right rectangular prism, and it is usually found with truncation of the basal angles, as in Fig. 5, aggregated in wedge-shaped fasciculi, and radiated to foliated, in twins, etc. The crystals are striated on the sides, and may be easily split in one direction; the hardness is 3·5—4, and the specific gravity 2·15—2·20. They comport themselves like heulandite before the blowpipe and with acids, and are generally colourless, passing into grey and brown-red. The chemical constituents are likewise lime with silicate of alumina and water, according to the formula $\dot{C}a\ \ddot{S}i + \ddot{A}l\ \ddot{S}i^3 + 6\ \dot{H}$. The localities are the same as those of the foregoing mineral, especially in the Faröes and Iceland, also in Scotland, Ireland, at the Hartz Mountains, and at St. Gothardt, etc. The following are also monoclinic lime zeolites; the *laumonite* or *lomonite* $= \dot{C}a^3\ \ddot{S}i^2 + 4\ \ddot{A}l\ \ddot{S}i^2 + 18\ \dot{H}$; the *leonhardite* $= 3\ \dot{C}a\ \ddot{S}i^2 + 4\ \ddot{A}l\ \ddot{S}i^2 + 15\ \dot{H}$.

The *epistilbite* is rhombic $= \dot{C}a\ (\dot{N}a)\ \ddot{S}i + 3\ \ddot{A}l\ \ddot{S}i^3 + 5\ \dot{H}$, so also are the *thomsonite* $= (\dot{C}a, \dot{N}a, \dot{K})^3\ \ddot{S}i + 3\ \ddot{A}l\ \ddot{S}i + 7\ \dot{H}$, the *prehnite* $\dot{C}a^2\ \ddot{S}i + \ddot{A}l\ \ddot{S}i + \dot{H}$, and the

$$\textit{phillipsite} = \left.\begin{matrix}\dot{C}a^3\\ \dot{K}^3\end{matrix}\right\}\ \ddot{S}i^2 + 4\ \ddot{A}l\ \ddot{S}i^2 + 18\ \dot{H}.$$

The *schubasite* crystallises in rhombohedrons, as Fig. 9 and 10, frequently in twins, of 4·0—4·5 hardness, and 2·0—2·17 specific gravity. The elements are $(\dot{C}a, \dot{N}a, \dot{K})\ \ddot{S}i^2 + 3\ \ddot{A}l\ \ddot{S}i^2 + 18\ \dot{H}$. It occurs pre-eminently at Steinau in Kurhessen, at the Kaiserstuhl, at Aussig in Bohemia, at Oberstein, in the Faröes, and in Scotland. The *cross-stone* or *harmotome* is a baryte and potash zeolite, which crystallises in right rectangular prisms, frequently aggregated in quadruplets of 4·5 hardness, and 2·39—2·43 specific gravity. It is found at Andreasberg in the Hartz mountains, at Strontian in Argyllshire, and at Old Kilpatrick, Dumbartonshire, at Oberstein, etc. Formula =

$$\left.\begin{matrix}2\ \dot{B}a\\ \dot{K}\end{matrix}\right\}\ {}^3\ddot{S}i^4 + 7\ \ddot{A}l\ \ddot{S}i^2 + 36\ \dot{H}.$$

Fig. 6.—Amalcime, Cubizite, Sarcolite.

The primary form is the cube, in the planes of which the crystals may be split; triple sharpening of the angles usually occurs, however, as in Fig. 6, so that at last perfect icositatetrahedrons arise as in the leucite. The crystals sometimes reach the size of the hand, and are usually reddish, passing into grey and white, translucent, of a vitreous-pearly lustre, of 5·5 hardness, and 2·06 specific gravity. Constituents: $\dot{N}a^3\ \ddot{S}i^2 + 3\ddot{A}l\ \ddot{S}i + 6\ \dot{H}$; it is therefore a soda zeolite, which crystallises in the regular system, and, before the blowpipe colours the flame distinctly yellow. It is easily fusible, and soluble in acids. It is found principally in the Fassathal, at Etna, in the Faröes, at Brewig in Norway, also in the trachyte of the Kaiserstuhl, where it has been confounded with the leucite.

The *faujasite* is a lime and soda zeolite, which crystallises in regular octahedrons, of vitreous to adamantine lustre, of 5·5 hardness, and 1·923 specific gravity. Formula: $(\dot{C}a, \dot{N}a)\ \ddot{S}i^4 + 3\ \ddot{A}l\ \ddot{S}i^2 + 8\ \dot{H}$. Is found in the amygdaloids of Sassbach, and at Annerode in Hesse, where it occurs with *phillipsite* in a porous basaltic lava.

Figs. 7 and 8.—Apophyllite, Ichthyophthalmite Albine.

This mineral crystalises in right square prisms, in general combined with truncation of the angles, as seen in Fig. 7, or in quadratic pyramids, more rarely in quadratic tables with truncation of the angles, or in foliated masses,

as Fig. 8, the *ichthyophthalmite* proper, which is distinguished from the other zeolites by the silicate of lime taking the place of the silicate of alumina. It is in fact a combination of double silicate of potash, with eight equivalents of simple silicate of lime, and sixteen equivalents of water, according to the formula: $\dot{K}$, $\ddot{S}i^2 + 8$ $\dot{C}a$ $\ddot{S}i +$ 16 $\dot{H}$. It has a hardness of 4·5 to 5·0, a specific gravity of 2·3—2·46, and is decomposed by acids; it melts readily before the blowpipe, swells up, colours the flame a yellow-red, and gives off water in the matrass. The colour varies from a glassy transparency to rose-red and brown.

Apophyllite is found especially at Andreasberg, in the Hartz mountains, and in the Faröe Islands; colourless crystals occur in Iceland and at Vicenza; the reddish and yellow *ichthyophthalmites* in the Fassathal, at the Seisser Alps; the milk-white *albine* at Aussig, in Bohemia.

The *pectolite*, radiated-fibrous, globulous, of pearly to silky lustre, of 5·0 hardness, and 2·69 specific gravity, belongs also to this species. It contains, however, with the silicate of lime, silicate of soda, and a little water, according to the formula: 3 $\dot{N}a$ $\ddot{S}i + 4$ $\dot{C}a^3$ $\ddot{S}i^2 + 3$ $\dot{H}$. It is white, passing into yellowish and grey, and is found in the amygdaloids of Monte Balco, and in the Fassathal.

The *wollastonite* or *table-spar*, oblique rhombic, white passing into grey and reddish, of vitreous lustre, 4·5—5·0 hardness, and 2·8 specific gravity, is a pure silicate of lime, containing 51·60 of silicate acid, and 46·41 of lime, according to the formula: $\dot{C}a^3$ $\ddot{S}i^2$. It melts without intumescence, burns brightly, and colours the flame a yellow-red. Is found at Auerbach on the Bergstrass, in radiated foliated masses; in Hungary, Finland, Pennsylvania, etc.

The *okenite* is nearly related to the apophyllite, occurs in fibrous radiated masses, and consists of silicate of lime and water, according to the formula: $\dot{C}a^3$ $\ddot{S}i^4 + 6$ $\dot{H}$. It is colourless, passing into yellow and bluish, of pearly lustre, translucent, of 4·5—5·0 hardness, and 2·28 specific gravity, is decomposed by hydrochloric acid, and comports itself otherwise like apophyllite. It is found in the amygdaloid of the Faröes, and of Iceland.

The *datholite* crystallises in oblique rhombic prisms, with different truncations of edges and angles, sometimes in clusters and fibrous *botryolite* and *fibrous datholite*. It is colourless, passing into grey, yellow, and green, friable, of vitreous lustre, translucent, cleavage in the direction of the lateral planes; the hardness = 5—5·5, the specific gravity = 2·95—3·0. Melts with intumescence to a transparent glass; when melted with salt of phosphorus it gives the yellow-green flame of boracic acid, and consists of borate and silicate of lime with water, according to the formula: $\dot{C}a^3$ $\ddot{S}i^4 + 3$ $\dot{C}a$ $\ddot{B} + 3$ $\dot{H}$. Occurs by preference at Andreasberg, the Hartz mountains, and at Kongsberg in Norway; also in Connecticut, New Jersey, and at Sonthose in Bavaria, and at Klause in the Tyrol; the botryolite at Arendal in Norway.

VI. CALCAREOUS MINERALS.

PLATE VII., Figs. 9—18, and PLATES VIII., IX., X. and XI., Figs. 1 and 2.

Carbonate of Lime.

Lime is one of the most widely distributed metallic oxides, and it performs an important part not only in the mineral, but also in the vegetable and animal worlds, since it constitutes an essential element of fixed organic frames. Phosphate and carbonate of lime, and sometimes also sulphate, oxalate, and malate of lime occur in most plants, the two first especially, in the ashes, and these two are again found in the bones and teeth of the higher animals, in the shells and coverings of the molluscs and crustaceans, in the dermal skeletons of the radiata, and in the stony habitations of the polypes. The carbonate of lime is most widely distributed in the mineral kingdom, the sulphate more sparingly, and more so still, the phosphate of lime; fluoride of lime is found chiefly in the metallic veins.

All these combinations of lime are, in their pure condition, colourless, and have a moderate hardness and weight; calcium itself has a specific gravity of only 1·577. They burn before the blowpipe with a white light, sometimes so brilliantly, that they blind the eyes (this is most strongly manifested with carbonate of lime), and colour the flame a yellowish red, especially when the specimen to be tested has been dipped in tallow or wetted with hydrochloric acid. The carbonate of lime occurs in two principal forms, which, although of the same chemical constitution, yet possess many physical distinctions, and so form one of the finest samples of dimorphism. The crystallisation is rhombohedral and right rhombic or prismatic; both varieties are composed of simple carbonate of lime, and the former has been called *calcite*, the latter *arragonite*. Both dissolve with effervescence in acids, and when burned give off 1 equivalent of carbonic acid = 43·972, leaving 56·028 of caustic lime; the calcite, however, preserves its form during the burning, while arragonite falls to a heap of pulverulent atoms. Arragonite is also always harder and heavier than calc-spar. Both occur crystallised, crystalline, fibrous, and compact; the latter varieties are commonly called *limestone;* the arragonites can, however, always be distinguished by its greater hardness and weight, which varies from 2·8—3·0, and they cannot be scratched by calc-spar crystals; while, on the contrary, the rhomboidal limestones can be scratched by the crystals of arragonite. In their relations to light they also differ essentially; both, indeed, refract light doubly, but calcite has only one, while arragonite possesses two optical axes—the fracture also differs much, the calcite, however it is crystallised, may be split into rhombohedral tables in three directions, while arragonite may generally be split, with difficulty however, in the direction of the rhombic prism and the planes of truncation of the acute lateral edges, and always presents uneven planes of fracture in the direction of the basal planes.

Figs. 9—14.—Rhombohedral Carbonate of Lime, Calc-Spar, Double Spar, Calcite.

The primary form is an intermediate rhombohedron of 105° 5′—105° 8′ (Fig. 9), in which directions all crystals may be alike easily split. There is still, however, a fourth crossing of laminæ, which falls perpendicularly on the principal axis, and therefore corresponds to the planes of truncation of the vertex. This rhombohedron is seldom found simple, but, for the most part, with single or several truncations of the vertical edges, as Fig. 10 shows; sometimes as a secondary, and sometimes as an acute rhombohedron (Fig. 12), and from three to six different rhombohedrons, combined with one another, not unfrequently occur; they may be recognised by their pyramidal planes, of which every alternate three are grouped round the principal axis. A separate series is formed by the unequal edged hexagonal double pyramids, scalenohedrons (Fig. 11), which occur sometimes by themselves, sometimes united as twins (Fig. 14), sometimes combined with dissimilar rhombohedrons, especially frequently in clefts and veins of the different chalk formations. A third series is formed by the hexagonal prisms, which originate in truncation of the basal angles of the rhombohedron, and occur sometimes in combination with the acute, sometimes with the obtuse rhombohedron, sometimes without these, with right terminal planes. Fig. 13 represents the first secondary rhombohedron, with the hexagonal prism, as it so frequently occurs in the metallic veins at the Harz, the Schwarzwald, the Erzgebirge, etc. All prisms have shorter tabular, and longer, frequently much striated, forms; the rhombohedrons have frequently long spear-like and acicular crystals, so that the calc-spar represents a variety of forms, equalled by no other mineral, about 800 having been described.

Stem-like, foliated, fibrous, crystalline-granular, dense, perfectly compact, earthy-friable, stalactitic (Fig. 17), with radiated fracture, pisiform or globular (Fig. 18), roe-stone-like and oolitic forms are the most usual. Under the name limestone, are comprised all those varieties of carbonate of lime which occur in large masses, but when these are white or finely coloured, and capable of polish, they are called generally, *marbles*. Thus the granular white marble of the primary formations is called saline or statue-marble, also absolutely white marble, and, according to the locality where it is found, Carrara, Tyrolese, Parian, and Hymetan marble. The other kinds are divided according to their colour; where it is single, into yellow, red, grey, black; where double, into black and white (Plate VIII., Fig. 5), grey and black (Fig. 7), variegated (Figs. 8 and 9), etc. *Fire-marble*, or *lumachelli*, is the name given to a limestone capable of polish, and coloured by fragments of a mussel or snail (Plate VIII., Figs. 2 and 6); such marbles as contain corals are called *coralline marbles* (Fig. 9); those which present figures of ruined walls, castles, buildings, etc., are called *ruin marbles* (Plate VIII., Fig. 1); *brecciated marbles* are such as are composed of fragments of differently coloured limestones (Plate VIII., Figs. 3 and 5; Plate IX., Fig. 4). Those calcareous stalactites which are marked with layers, and which take on a polish, are called striped marbles (Plate IX., Fig. 2); all those where two or more colours are especially conspicuous are called variegated marbles (Plate IX., Figs. 1 and 5—8), according to the formation we distinguish between salt and fresh-water limestone. Limestone appears very frequently, not only as the petrifying medium of the remains of conchiferous animals, but also as the mother-stone of the petrifactions which are often embedded in it by thousands. As in all the limestone of the stratified formations, these remains consist of the coverings of marine animals, this is called marine limestone. An example of this is seen in Fig. 6, Plate VIII., which represents a tertiary marine limestone from the tertiary formation, with sections of turbinated shells (*Pyramidella Turbinella?*), cut through in different directions; also in Plate IX., Fig. 3, which is a fragment of gryphitic chalk, with bivalve shells *(gryphæa arcuata)*, from the lias near Stuggart. Such limestones are called fresh-water limestones, as, from their containing the remains of land and freshwater animals (*Helix*, *Pupa*, *Lymnæus*, *Paludina*, *Planorbis*, *Valvata*, etc.), can be recognised as the deposits of fresh water. To these belong, for example, Figs. 1 and 2, Plate IX., which are from the tertiary formation of the Swabian Alps at Böttingen, near Münsingen, and present a similar appearance to the sprudelstein of Carlsbad (Plate VII., Fig. 15). Mineral water limestone is the name applied to such varieties of calcite as are known to have their origin in mineral springs which are rich in carbonic acid, as, for instance, the tufaceous limestones of Canstatt, which are produced under the eyes of the observer. Tufaceous limestone usually includes all the more recent kinds of calc-spar that have been produced either in mineral springs or in rivers. They are generally extremely porous, of an earthy fracture, sometimes crystalline-cellular, sometimes they take reticulated, interlaced, shrub-like forms by encrustation of *chara* and similar plants; they occasionally assume coralline or peg-like forms. This is especially the case near waterfalls, where the spray sometimes produces even very fine clustered or globular forms.

According to the formations we distinguish between the plutonic or primary limestone, stratified limestone of the different formations, Silurian, Devonshire, lias, Jurassic, chalk, tertiary diluvial, and alluvial limestone. There are also limestones of volcanic origin, as, for example, at the Kaiserstuhl there is a layer of crystalline lime mixed with mica in the dolerite, and vulcanised or stratified limestone changed by volcanic minerals, which is usually remarkable for its marble-like mixture of colours, as, for example, Plate IX., Figs. 5—8, and limestone of the Jura formation from the neighbourhood of volcanic rocks in the Swabian Alps.

The distribution of limestones is extraordinarily great, and they play an important part in each formation. The application of this mineral to quick-lime and other chemical purposes, to architecture, for the construction of buildings and roads, for monuments, sculpture, and also to lithography, etc., are generally known.

Chalk-marl is the name applied to the limestones which are more or less rich in clay, aud which are soluble in acids, with separation of the muddy clay. The amount of clay contained in marl varies from 25 to 30 per cent, and when burned it forms a hydraulic mortar, that is, a cement which hardens under water, and is extremely valuable for building in water or by the shore. These rocks are found in most of the chalk-formations, especially in the lias and Jura. The marls frequently form round-

ish or kidney-like masses; sometimes they are of a peculiar peg or nail-shaped form, the so-called nail-chalk, or they lie in layers between other limestones. Marls very rich in clay or sand are called *clay* or *sand-marl.* They are very readily decomposed in the atmosphere, and form a rich, more or less sandy soil.

PLATE VII., Figs. 15 and 16, and PLATE X., Figs. 1—3 and 5—6.

Arragonite.

The primary form is a right rhombic prism of 116° 11′. This form is generally found with truncation of the acute lateral edges (Plate VI., Fig. 2), sometimes also with truncation of the basal edges, and aggregated as twins (Plate X., Fig. 1); in this case the crystals are often quite transparent or yellowish. The former variety occurs at Molina in Arragon, the latter at Bilin in Bohemia. Besides these it presents pyramidal and acute forms (Plate X., Fig. 3), from Salzburg); fibrous forms are also met with, like the sprudelstein of Carlsbad (Plate VII., Fig. 15), which is partially reddened by oxide of iron, or shrub-like forms, sometimes of coralline structure like the so-called flos-ferri (Plate VII., Fig. 16), a finely fibrous arragonite, with an external pearly or silver lustre. It is conjectured that most arragonites have been formed at a higher temperature from the carbonaceous waters of the limestone mountains, and that the distinction between arragonite and calcite is closely connected with the relations of temperature; there are arragonites, too, which contain strontia, and even oxide of lead, as, for instance, the *tarnovicite*, a fibrous arragonite from Tarnowitz in Silesia, which contains from 2·0 to 3·8 of the carbonate of lead. Most of the arragonites are, however, pure, simple carbonate of lime, as has already been stated. Carbonate of magnesia, and the protoxides of manganese and iron, are also found in many, especially in the compact, varieties of arragonite; in this class is the so-called *agate-marble* from Constantine in Algiers (Plate X., Fig. 5), which is translucent, and is marked by greenish and occasionally yellowish stripes, and also the veined variety from Gibraltar (Plate X., Fig. 6) and Bergamo in Northern Italy. These, like the other arragonites, are also distinguished from the common limestones by their greater weight (= 2·8—3·0), and hardness (3·5—4·0). Their behaviour in the fire, and towards acids, has been given above. The distribution of arragonite is much more limited than that of the calcite, and, except being employed for marble, and for small objects of art, as already mentioned, it has no further application in the arts.

Fig. 4.—Bitter Spar and Brown Spar, Dolomite.

This mineral differs from calcite by its crystalline form, which is a rhombohedron of 106° 16′; it is essentially distinguished from it, however, by containing carbonate of magnesia, almost in equal proportions, sometimes also carbonate of manganese and iron; the hardness (= 3·5—4·01), and the specific gravity (2·81—2·90) are also greater. The latter varieties are generally called brown-spars, the former bitter-spars, and, if they occur in larger crystalline granular masses, *dolomite.* The colour varies from white to yellow, grey, reddish (Plate X., Fig. 4), and even to black. The crystals are essentially separated from the calcite, inasmuch as they usually present intermediate, and more rarely obtuse, rhombohedrons; they are drusy, often present curved planes, are but slightly transparent, and are, for the most part, of a pearly lustre, and are dissolved only slowly in acids; before the blow-pipe they are phosphorescent, indeed, and become caustic, imparting to the flame a yellow-red colour, but most of them, at least all the brown-spars, take a brown or black colour.

The chemical constituents vary. Dolomite or bitter-spar contains, on an average, 55·0 carbonate of lime, and 45·0 carbonate of magnesia (= $\dot{C}a\,\ddot{C} + \dot{M}g\,\ddot{C}$); in brown-spar the lime, and sometimes the magnesia, is partially replaced by carbonate of iron and manganese, the bitter-spar from Kolosuruk in Bohemia for three equivalents of $\dot{C}a\,\ddot{C}$, has only two equivalents of $\dot{M}g\,\ddot{C}$.

Its occurrence is limited, for the most part, to veins containing ores and clefts in the primary and stratified rocks; *dolomite* is found in irregular masses, sometimes, however, also in regular beds of remarkable thickness and extent, especially in the lime mountains of the Alps, Southern Tyrol, of the Zeckstein, shell limestone, and white Jura especially. They present sometimes the appearance of granular limestone, and are employed in building. They are also used for the preparation of carbonate and sulphate of magnesia.

The carbonate of magnesia, *magnesite*, occurs crystallised or crystalline as magnetic spar, similar to bitter-spar, and has likewise a rhombohedron of 107° 22′ for a primary form; it is distinguished from it, however, by greater hardness (= 4·0—4·5), and specific gravity (= 2·9—3·1), as well as by chemical composition. It is a pure carbonate of magnesia = $\dot{M}g\,\ddot{C}$, consisting of 48·31 of magnesia and 51·59 of carbonic acid; it is dissolved by acids with effervescence, is phosphorescent before the blow-pipe, and, when wetted with a solution of cobalt, gives a rose-red colour. There are two kinds of magnesite; the one compact, sometimes passing into earthy, is white, and contains, for the most part, some silica, as, for instance, that from Sassbach at the Kaiserstuhl, and from Hrubschütz in Moravia. Crystals are found at St. Gothard, at Greiner in the Zillerthal, and in the Fassathal, generally with talcose or chloritic schist.

Breunerite is a magnesite mixed with carbonate of iron and manganese; *pistomesite* consists of three equivalents of carbonate of magnesia and two of carbonate of iron, and is found at Flackau in Salzburg.

The *periclase* of the Somma at Naples is a magnesia, containing oxide of iron, and crystallising in octahedrons or cubes. Hardness 6·0, specific gravity 3·75.

Hydrate of magnesia, brucite —The primary form is an hexagonal prism, white, passing into green and grey, more frequently occurring in radiated-foliated masses, of 1·0—1·5 hardness, and 2·35 specific gravity ; it is a simple hydrate of magnesia, $\dot{M}g\ \dot{H}$, which is dissolved without effervescence in acids, and occurs at Swinaness in the Isle of Unst, Shetland, and at Hoboken in New Jersey.

Meerschaum is the name given to a hydrous silicate of magnesia = $\dot{M}g\ \ddot{S}i + \dot{H}$, occurring in dense white masses, of an earthy appearance, which feels light, adheres to the lips when wetted, and therefore possesses a low specific gravity of 1·27—1·6 ; the hardness varies from 2·5—3·0. It is found in dense masses in Livadia and Natolia, also at Hrubschütz in Moravia. When freshly dug it is tough, and may be kneaded to a dough, out of which the celebrated pipe-heads are manufactured. That from Natolia is especially valued for this purpose.

Steatite or *Soapstone, Spanish Chalk* is a similar silicate of magnesia, which sometimes contains a small quantity of clay and oxide of iron. It is, however, unctuous to the touch, and sometimes occurs in altered crystals of quartz—as for example at Göpfersgrun in Bayreuth, and, in dense masses, it is employed in the manufacture of all kinds of objects of art, for polishing glass and marble, etc.

Figs. 7—10. Gypsum, Selenite.

Gypsum crystallizes in oblique rectangular or right rhombic prisms, as its primary form, inasmuch as the crystals can be placed on a rectangular (Fig. 7), or on a rhomboidal plane. Truncations of the greater basal edges and of the lateral edges (Fig. 8) are, however, frequently found ; yet more frequently twins arising from the aggregation of two such crystals (Fig. 9), or large lenticular twins, which present wedge-shaped forms (Fig. 10). The latter variety occurs especially fine at Montmartre, near Paris, the former principally in the beds of rock-salt at Bèx, in the county of Maadt in Salzburg, in the lower beds of shell-limestone in Swabia and Thuringia, in many English localities, and elsewhere. Very large crystals, often remarkably curved, are found in Coburg and in Oxfordshire. Gypsum is found, fibrous and of silky lustre, especially fine at Aargau, in Nottingham, and Derby, also in the marl of Swabia, etc. ; a foliated variety occurs imbedded in the common earthy or lamellar gypsum. Common gypsum is found in almost all limestone rocks and clay marls in the stratified formations, especially in the shell-limestone, also in the tertiary mountains (Paris, Hohenhoven in Upper Swabia, etc.), and, when pure, it is usually applied to economical purposes, and to the arts. *Alabaster* is a finely granular variety, sometimes compact and translucent ; it is distinguished from gypsum by its solidity and capability of polish, especially as it occurs in Tuscany and other Italian localities.

Gypsum is characterised by its white or light colour, white streak, vitreous to pearly lustre, and slight hardness (= 2·0), and specific gravity (= 2·2—2·4). It is easily scratched by the nail of the finger. It is decomposed with difficulty, and is flexible in thin plates. The crystallised *gypsum-spar* or *selenite* can be split in the direction of the rhomboidal planes ; in another direction it breaks, and in a third it bends, a behaviour common to no other minerals in equal masses. The chemical constituents are simple sulphate of lime with two equivalents of water = 33·0 lime, 46·0 sulphuric acid, and 21·0 water ($\dot{C}a\ \ddot{S} + 2\ \dot{H}$). It is soluble in about 460 parts of water, and imparts to it an insipid, earthy, somewhat bitter taste ; the solution gives sulphuric acid and lime reactions. The waters of many springs which rise from gypsum rocks are quite saturated solutions of gypsum, and are therefore not quite sweet, and entirely unfit for the preparation of colours, beer, leather, etc., the more so on account of its not being separable by heat, as is the case with carbonate of lime. It is not at all, or almost imperceptibly, soluble in acids. Before the blow-pipe it melts, gives off water, reddens the flame, and is reduced to sulphuret of calcium ; the sulphur is usually, however, soon given off, and pure lime, which is easily recognised by its bright flame, remains. When melted along with fluor spar, it melts readily to a clear pearl, which grows dim on cooling.

In the arts gypsum, when deprived of its water by burning at a slow red heat, and mixed with water, is used for casting statues, ornaments, and medals, and for friezes, chamber ornaments, the imitation of marbles, as stucco and mortar ; the gypsum containing lime, from the neighbourhood of Paris, is frequently employed for the latter purpose, and is called *plaster of Paris.*

The gypsum containing rock salt, the bituminous clay gypsum of the salt rocks, is used as a manure, especially in wet, damp soils, and for raising leguminous plants. Alabaster is made into statues, vases, time-pieces, and other works of art, especially in Tuscany.

Figs. 11 and 12.—Anhydrite.

The primary form is a right rectangular prism (Fig. 12), which may be split in all directions, but most easily in that of the lateral planes ; truncations of the angles (Fig. 11), and of the lateral edges, are also found, as well as crystalline foliated granular masses, which have been called *vulpinite*, and in compact kidney-shaped masses, as *tripe-stone.* The colour is rarely pure white, more frequently reddish sky-blue or grey ; the transparency is very slight, the lustre between vitreous and pearly. The crystals are friable, the crystalline varieties very difficult to separate ; hardness = 3·0—3·5, and specific gravity = 2·7—3·0, both being somewhat greater than in common gypsum. In the matrass it gives off no water, but otherwise comports itself before the blow-pipe like gypsum. The elements are one equivalent of lime = 41·53, and one equivalent of sulphuric acid = 58·47. Formula $\dot{C}a\ \ddot{S}$. The blue variety contains a small amount of iron, the grey is coloured by carbonaceous elements. When powdered and mixed with water, it gradually takes up two equivalents, and becomes changed into common gypsum.

The *anhydrite* usually accompanies rock-salt at Bex, Wilhelmsglück, Salz, etc. At the last-mentioned place fine sky-blue specimens are found in radiated granular, passing into foliated and compact masses, which take on a fine polish, and are used as marble.

Figs. 13 and 14.—Apatite, Asparagus-Stone, Phosphorite, Moroxite.

The primary form is a regular hexagonal prism (Fig. 13), which may be distinctly split in the direction of the lateral planes, and with more difficulty in that of the terminal planes. Extension of the four lateral planes sometimes occurs, so that it becomes a rhombic prism; truncations of the basal edges and angles, as in Fig. 14, double and treble truncation of these, and also of the lateral edges, are also found, so that this mineral exhibits, as few others do, the manifold forms of the hexagonal system. It occurs, moreover, in roundish grains, mostly of a yellow-green colour, the so-called *asparagus-stone*, as, for example, in the Zillerthal, or in long striated verdigris-coloured prisms of the form of rock-crystal—the so-called *moroxite*, at Arendal in Norway, or in dense radiated fibrous or compact masses—the *phosphorite*, as, for example, at Amberg, at Bavaria, in Moravia, and Bohemia, sometimes also in an earthy form, as at Szigette in Hungary, and in Spain.

The colour varies from white to yellow, blue, green, red and brown. The crystals are of a vitreous lustre; in the planes of fracture the lustre is resinous, translucent to transparent, they are scratched by felspar, and scratch fluor-spar; they have, however, the fifth degree of hardness, and a specific gravity of 3·1—3·3. The constituent elements are basic phosphate of lime, with one-third of an equivalent of fluoride of calcium or fluoride of magnesium. Formula, $Ca\ Cl\ (Fl) + 3\ \dot{C}a^3\ \ddot{P}$. The powder burns when strewed on charcoal, or in a loop of heated platinum wire, with a greenish appearance; is not soluble in water, readily, however, in nitric acid, without effervescence. Before the blow-pipe alone it melts only at the edges; with boracic acid and salt of phosphorus, to a clear glass; with boracic acid and iron wire, it forms in the inner flame phosphuret of iron. Generally found accompanied by tourmaline, berylla, tin, etc., in clefts and veins of the primary rocks. The finest specimens are those from Schlackenwald and Ehrenfriedersdorf, in the Erzgebirge, and at St. Gothard.

The compact-phosphorite has lately been employed as a manure instead of bone-dust, and in order to supply plants with the necessary quantity of phosphate of lime. Phosphate of lime appears to be present in most limestones and marls, as it is known that it is contained in the ashes of most plants, and that phosphates have always been supplied to animals by the vegetable world.

Plate X. Figs. 15—18, and Plate XI. Figs. 1 and 2.

Fluor-spar, Fluoride of Calcium.

The primary form is a regular octahedron (Fig. 15), which seldom appears, however, in its simplicity; the most frequent form is the cube, which usually presents crystalline drusy planes (Plate XI., Fig. 1), or is truncated at the angles (Fig. 16). Not unfrequently there are double truncations of the edges of the cube (Fig. 17), a combination of the cube with the pyramidal cube; simple truncation of the edges of the cube is more rare (rhombic dodecahedron), or the hexagonal pointing of the angles of the cube (Plate X., Fig. 18), being the union of the cube with forty-eight sided solid. Frequently the crystals are aggregated as twins (Plate X., Fig. 17, and Plate XI. Fig. 1). Attached crystals also occur (Plate XI., Fig. 2). It is, moreover, found dense and granular, especially so in the veins of the primary formations, usually along with many lead and silver ores, or perfectly compact, as at Stolberg on the Harz, and in Cornwall, or earthy as at Freiberg in the Erzgebirge, etc.

The colour varies from white to rose-red, yellow, violet, green, and even to a very fine blue; many crystals exhibit dichroism, having by reflected light a yellow or blue, and by transmitted light a red or emerald-green colour, as, for example, the fine crystals from Derbyshire. (Plate X., Fig. 17.) If a pencil of light be allowed to fall on such a green crystal, a magnificent cone of blue will appear. This property has been called *fluorescence*. The crystals admit of cleavage only in the direction of the octahedron, and present even surfaces of fracture. They are vitreo-lustrous, for the most part transparent, of 4·0 hardness, and 3·0—3·3 specific gravity. The chemical constituents are simple fluoride of calcium = Ca Fl, or 51·87 calcium and 48·13 fluorine. Water and weak acids have no effect on it; but when powdered, and sprinkled with concentrated sulphuric acid, fluoric vapours are developed, which corrode glass and render it dim. Before the blow-pipe it decrepitates, when cautiously heated for some time, and afterwards put in a loop of platinum wire, it phosphoresces with a blue or green lustre; also when sprinkled over charcoal. It is fusible to a dim pearl, with borax and salt of phosphorus to a clear glass, with gypsum to a clear pearl, which becomes dim when cooled. The finest octahedral crystals, of a rose-red colour (Fig. 15), occur at St. Gothard and on the Grimsel; the green varieties in Hungary and Siebenbürgen; of remarkable size in Graubündten; the yellow in Saxony; the violet (Plate XI. Fig. 1) in Cumberland; those with blue and green play of colours in Derbyshire; very fine groups of cubes, partly in combination with the 48-faced solid, are found at Waldshut on the Rhine, and in the Münsterthal near Freiberg; dark blue cubes, with truncation of the angles, at Salzburg, and bright green ones at Stolberg in the Harz. Stem-like, violet and white-striped masses (Plate X. Fig. 2) occur at Alston in Cumberland, and are there made into all kinds of objects of art—cups, vases, etc.

Fluor-spar is used principally as a flux for melting ores difficult of fusion, which it promotes, and it is from its use as a flux that its name has been derived. It is used also as an ingredient in enamel, and for the glazing of porcelain; further, in the preparation of hydrofluoric acid, for the purpose of etching on glass.

VII. COMPOUNDS OF BARYTA.

Baryta is the heaviest of all the oxides of the metals of the alkalis; hence its name, which is derived from the Greek Βαρυς, heavy. Its combinations are not numerous; in general they are colourless, 3·6—4·87 specific gravity, hardness from 3·0—3·5, and in comparison with compounds of chalk they are found more sparingly, and principally in veins. They colour the blue flame of the blow-pipe greenish-yellow, and do not tarnish the charcoal, whereby they are essentially distinguished from the similar compounds of lime and lead.

FIG. 3.—WITHERITE, CARBONATE OF BARYTA.

The primary form is a right rhombic prism (Fig. 4) of 118° 30′ and 61° 30′; the prism may be split in the direction of the primary planes, and in that of the truncated planes of the acute lateral edges, so that a hexagonal prism is formed. The most frequent form is a hexagonal pyramid, united to a second double pyramid arising from further truncation of the basal edges (Fig. 3). Spear-like, radiated, and compact forms also occur, as with arragonite (Plate X. Fig. 3). Generally colourless, translucent, lustre vitreous to fatty, friable. Hardness, 3·0—3·6. Specific gravity, 4·2—4·4. Soluble in acids with effervescence. Constitution; simple carbonate of baryta, = Ba C; the carbonic acid is given off by heating, leaving 79·66 of oxide of barium, which is soluble in pure water, gives an alkaline reaction, and becomes clouded by the addition of sulphates. The solution in hydrochloric acid does not change the alcoholic flame. It melts before the blow-pipe to a white bead, burns and colours the flame to a yellowish-green. Is found in Salzburg, Hungary, Styria, and in especially fine crystals in England and Scotland.

Its use is limited to the preparation of the different salts of baryta and chemical re-agents; the powder serves for the destruction of rats and mice, and it is poisonous to warm-blooded animals. It has also been employed in this country in the manufacture of plate-glass, and in France in the preparation of beet-root sugar.

FIGS. 4—6.—HEAVY SPAR, SULPHATE OF BARYTA.

Also right-rhombic, the angles of the lateral edges = 101° 42′ and 78° 18′. Cleavage in the direction of the planes of the rhombic prism, most easy in that of the terminal planes. This primary form is found very frequently, mostly in low tables like Fig. 4; sometimes, however, with truncation of the acute or of the obtuse angles, or also with truncation of all the basal edges, as in Fig. 5. The horizontal prism (Fig. 6) originates in extensive truncation of the obtuse angles by themselves. It very frequently occurs in coarsely foliated masses; it is more rarely earthy or mealy, and, most seldom of all, compact and finely granular; the radiated baryta or *Bolognese-spar* presents the peculiarity of phosphorescence in the dark after a long exposure to the sun. It is found at Bologna. The colour is generally white, passing into grey. It is friable, of vitreous lustre, translucent, of 3·6—3·5 hardness, and 4·17—4.487 specific gravity. The elements are simple sulphate of baryta, Ba S, with 65·63 of oxide of barium, and 34·37 of sulphuric acid.

Insoluble in water and acids; decrepitates before the blow-pipe, phosphoresces with greenish light, melts somewhat more easily than felspar to a white enamel, and in the inner flame becomes changed into sulphuret of barium, which, on a piece of silver wetted with water, leaves a black stain, and sulphuretted hydrogen is given off. The test dissolves with the same phenomena in hydrochloric acid; the solution gives with sulphates a white precipitate, which is insoluble in nitric acid. The crystallised barytes occurs in Hungary, Bohemia, at Klausthal, at the Schwarzwald, etc., and the conchoidal foliated varieties in veins of the primary and stratified rocks, along with silver, iron, copper, and cobalt ores. When it is found pure white, in large masses, it is ground fine and mixed with white lead, for the purpose of lowering the price. It is also used in the preparation of other salts of baryta, from which partially pulverulent sulphate of baryta is made, and this is used as a colour for paint.

The *baryto-calcite* and *alstonite* are combinations of carbonate of lime and carbonate of baryta in different proportions, which occur at Alston Moor, Cumberland. The sulphato-carbonate of barytes occurs at Brownley Hill in Cumberland, and at Dalton Fells, Westmoreland.

VIII.—COMPOUNDS OF STRONTIA.

Strontium is a yellowish white metal, of 2·54 specific gravity, and its oxide, strontia, forms the principal element in these minerals. Generally speaking, they resemble the baryta compounds; they have, however, a lower specific gravity (3·5—4), and they colour the blue flame of the blow-pipe a bright purple red.

Strontianite, or carbonate of strontia, has for its primary form a right rhombic prism of 117° 32′ and 62° 28′, and occurs like carbonate of baryta in hexagonal pyramids (Fig. 3), and in spear-like acicular crystals, like arragonite (Plate X., Fig. 3), with a hardness of 3·5, and a specific gravity of 3·6—3·8. The chemical constitution is simple carbonate of strontia—Sr C. When reduced to powder, it gives on live charcoal a reddish lustre. Before the blow-pipe, it swells up and colours the flame red without melting. In acids, it dissolves with effervescence. It is found sparingly at Strontian, in Argyllshire, at Salzburg, Braunsdorf in Saxony, and sometimes also in the ammonites (*ammonitus angulatus*) of the lower lias near Stuggart.

FIGS. 7—9.—SULPHATE OF STRONTIA, CELESTINE.

The primary form is a right-rhombic prism of 104° 48′ and 75° 12′ Cleavage in the direction of the planes of the primary form, especially in that of the terminal planes. In other respects, it is like the sulphate of baryta. Truncation of the obtuse angles (Fig. 7), or of the obtuse and acute angles (Fig. 8) occurs, drusy aggregations are also found, partly with double truncation of the angles (Fig. 9), as well as radiated crystalline-granular masses. The crystals are frequently a sky-blue, which is also the colour of fibrous celestine—the so-called *schutzite* of Jena and of Pennsylvania, and which has also been found at Aust Ferry, near Bristol. Transparent, translucent, friable; hardness 3·0—3·5, sp. gr. 3·6—4·0. The transparent crystals refract the rays of light double, and have a bright vitreous lustre. The chemical constituents are simple sulphate of strontia, $\dot{S}r\ \ddot{S}$ = 56·36 of strontia, and 43·64 of sulphuric acid, usually with traces of the oxide of iron, carbonate of lime, and water. There are also lime, and baryta celestines. It decrepitates before the blow-pipe, but not so violently as baryta, and melts to an enamel, reddening the flame. Insoluble in acids. The finest crystals are found at Girgenti in Sicily, mostly in native sulphur (Fig. 9); also in Hungary, North America; sometimes also with strontianite at Stuttgart, at Soluthurn, and Vicenza; the radiated foliated variety occurs principally in the Fassathal, the fibrous at Jena, the calcareous at Paris, in thick crystalline masses of a greenish-grey colour. Celestine (Latin *cœlestis* sky-blue) is used principally in the preparation of nitrate of strontia, which is used for producing the *red-fire* in fireworks, for which purpose it is generally obtained in this country in the neighbourhood of Bristol, where it occurs in granular masses.

IX. SALTS OF POTASH.

Pure compounds of potash are of rare occurrence in nature, and they are for the most part products of decomposition, sometimes by fire and volcanoes, and sometimes by the action of nitric acid on other minerals. They are thus generally double combinations, as we may have seen in considering the felspars. The following compounds are true salts, that is, combinations of acids with bases; they are soluble in water, and impart a violet colour to the flame of the blow-pipe.

FIG. 10.—SULPHATE OF POTASH.

The primary form is a right-rhombic prism of 112° 8′, and 67° 52′; hexagonal double pyramids (Fig. 10) occur most frequently, however, with a specific gravity of 1·73, and a hardness of 2·5—3·0; small acicular crystals and crystalline masses are also found in many lavas of Vesuvius. The colour is white, passing into yellow, bluish, and grey. It dissolves in five times its volume of boiling water, and has a brackish taste. The elements are, potash 54·75 parts, and sulphuric acid 45·25 parts, simple sulphate of potash = $\dot{K}\ \ddot{S}$. Before the blow-pipe it melts with crepitation, and forms sulphuret of potassium in the inner flame, which is soluble in water, and blackens silver.

FIG. 11.—POTASH-ALUM, ALUM, ALUM-SALT.

Alum crystallises in regular octahedrons, which sometimes assume a ladder-like form, like Fig. 11. Cubes also are found with and without truncated angles, as well as fibrous, capillary, and stalactitic varieties. Colour, white, grey, yellow. Lustre, vitreous. Translucent. Hardness 2·0—2·5. Sp. gr. 1·75—2·0. Readily soluble in an equal weight of hot water, and very large crystals may be obtained from the solution by occasionally stirring round small crystals that have been introduced, and by gradually allowing the fluid to evaporate. The taste is a sweetish astringent, somewhat sour, and it has an acid re-action. The chemical composition is sulphate of potash with sulphate of alumina, and 24 eq. of water = $\dot{K}\ \ddot{S} + \ddot{Al}\ \ddot{S}^3 + 24\ \dot{H}$. It melts easily when heated, and swells up to a great extent; it colours the flame violet, and is made blue by nitrate of cobalt.

Potash-alum is found as a product of burning coal beds at Saarbrück, Duttweiler, and frequently in fine crystals, in the department of Aveirons in France; fibrous or efflorescent in the alum-shale of the Upper Palatinate, in Saxony, and Swabia; also at Whitby in Yorkshire, and at Hurlet, near Paisley, and is used for the manufacture of crystallised alum for dyeing, and other purposes. Alum is, however, principally prepared from alum-stone, from the bituminous clay-slates of the stratified formations impregnated with pyrites, and partly, too, as an after-product in the manufacture of green vitriol (sulphate of iron), etc.

Alum-stone occurs in thick masses, and in obtuse rhombohedrons of 5·0 hardness, and 2·67—2·69 sp. gr. It is a triple-sulphate of alumina, consisting of 12 eq. of alumina, with 1 of simple sulphate of potash, and 8 eq. of water. Insoluble by itself in water, when heated and lixiviated with water it gives the Roman alum which used to appear in commerce in small dim octahedrons, and on account of its purity, was principally employed for scarlet dyes. The best were prepared at Tolfa, in the Papal States, from the rough alum-stone found there; latterly, however, it has been found in great masses in Hungary and Siberia.

There are also soda, ammoniacal, manganese, magnesia, and iron alums, in which these bases take the part of the potash, and most of them, owing to the alumina which they contain, are also applicable to dyeing. The *feder-alum* (feather alum) is a tolerably pure iron-alum, which occurs in asbestus-like needles, of a yellowish colour, principally as an efflorescence in many alum-shales. This shale is nothing else than bituminous clay-schists, interspersed with sulphate of iron, which is readily decomposed by the atmosphere, especially if it has first been slightly heated, and it occurs in the neighbourhood of many stone and brown coals, particularly also in the lias formation, and often in considerable quantity.

Figs. 12 and 13.—Potash-saltpetre, Nitrate of Potash, Saltpetre.

The primary form is a right-rhombic prism of 119°, with the cleavage in greatest perfection, parallel to the planes of the sides and to the planes of truncation of the acute lateral edges; transversely, however, it presents a conchoidal uneven plane with a greasy lustre; externally the lustre is vitreous. More frequently truncations of the acute lateral edges, and of all the basal edges occur, so that a combination of the prism with the hexagonal pyramid appears, similar to that of the quartzoid (Fig. 13), or a double truncation of the acute angles (Fig. 12). The natural crystals are mostly very small and irregular, like the Indian saltpetre which comes to Europe from the course of the Lower Ganges, in impure crystalline grains; but by dissolving in water, and gradually cooling it, very fine crystals can be obtained. Pure saltpetre is colourless, transparent, friable, of 2·0 hardness, and 1·9—2·0 sp. gr. It is simple nitrate of potash; $\dot{K}\,\dddot{N}$, composed of 46·56 potash and 53·44 nitric acid. As it is found in nature, it generally contains a little carbonate and sulphate of lime, bitumen, etc. A solution in water has a cooling salt taste, slightly acid. Sprinkled on live charcoal it decrepitates and melts. In the platinum forceps, it colours the flame of the blow-pipe violet, by which it may be easily distinguished from soda-saltpetre. It occurs in Hungary and Siberia in considerable quantities. Saltpetre is now generally artificially prepared in what are called saltpetre-plantations, by mixing up rich mouldy earth with burned lime, and the ashes of plants moistened with various animal substances, and exposed to the influence of the atmosphere.

Saltpetre is used in medicine, for the preservation of meat, for making gunpowder, nitrates, and other preparations.

The *sylvinsalz*, which has of late years frequently been found in considerable quantity as an efflorescence of lava, particularly at Vesuvius in 1822, is a chloride of potassium more or less mixed with chloride of sodium, which occurs in bluish crystalline masses, and when moistened with sulphuric acid, it gives off hydrochloric acid, and otherwise gives the reactions of soda and potash. The amount of chloride of sodium varies from 46·2 to 62·0 per cent, and it may be used both for the preparation of chlorine and hyrochloric acid, and of the compounds of potash and soda.

X. SALTS OF SODA.

The compounds of soda which we are about to enumerate are more widely distributed in nature than the potash salts, and moreover, they sometimes occur of remarkable purity. All of them are readily soluble in water, have a saline taste, and colour the flame of the blow-pipe a deep yellow. They are compounds of inorganic acids, with the oxide of sodium, or of chlorine with sodium; the latter class are the most important.

Figs. 14 and 15.—Carbonate of Soda, Soda.

The primary form is an oblique rhombic prism of 103° 84′ and 76° 12′, which generally occurs combined with truncation of the basal edges (Fig. 15); sometimes, however, it is found with truncation of two basal and lateral edges. More frequently crystalline granules and salt-like crusts occur, more or less mixed up with gypsum, chloride of sodium, and earthy substances of a white, grey, or yellow colour. Easily soluble in water; of 1·0—1·5 hardness, and 1·4—1·5 specific gravity. The constituents are simple carbonate of soda, with ten equivalents of water = $\dot{N}a\,\ddot{C} + 10\,\dot{H}$. The crystals crumble down in the atmosphere, and give off their water of crystallization; they melt very readily before the blow-pipe, and colour the flame yellow. When held in the outer flame in a loop of platinum wire, with a small amount of oxide of manganese, it gives a fine greenish-blue coloured pearl of manganate of soda, which becomes dim on cooling. It is found in large quantities in the natron-lakes of Lower Egypt, westward from the Nile, whence in earlier times it was brought by traders; at Debrecsin, and in other parts of Hungary, the soil is so strongly impregnated with soda that the land is sometimes covered with white acicular crystals of this salt. In former times much soda, was obtained from the ashes of sea-plants; now-a-days it is mostly extracted artificially from rock or sea-salt. It is used in the manufacture of soap and glass, for bleaching, and for many chemical preparations; also in a pure state as a blow-pipe test, and for distinguishing the different silicates.

Trona or *urao* is another compound of sesqui-carbonate of soda and water = $\dot{N}a^2\,\ddot{C}^3 + 2\,\dot{H}$, which occurs in oblique rhombic prisms of 103° 15′, generally with truncation of the obtuse angles (Fig. 14), of 2·0—3·0 hardness, and 2·11 specific gravity; vitreous lustre, colourless, passing into grey and yellow, translucent, not decomposed by the atmosphere, readily soluble in water, and of a tolerably alkaline taste. It is found in Egypt and other parts of Northern Africa, as well as at Lagunilla in Columbia, and may be used as soda. It also behaves like soda before the blow-pipe. Soluble in acids with effervescence.

Figs. 16—20, 21.—Rock-Salt, Chloride of Sodium, Common Salt.

The primary form is the cube, with cleavage in the direction of the planes. Combinations of the cube and octahedron, however, occur also (Fig. 20), and truncations of the edges; crystalline-granular masses, of the appearance of coarsely-grained quartz, are more common. Fibrous, foliated, and compact forms occur in an isolated condition. In general colourless, the crystals sometimes transparent in the highest degree, sometimes blue or red. Especially fine sapphire-blue varieties are obtained in the Salzburg district; finely granular and fibrous rock-salt, reddened by oxide of iron, is found especially at Hallein and Berchtesgaden; a brownish-red and long fibrous variety occurs at Wilhelmsglück on the Kocher (Fig. 16), where the granular salt reaches the thickness of from 20 to 30 feet, and the lower layers are crystallized. Cubes of a foot in diameter, and perfectly transparent, have been found here. Fracture even, of vitreous to fatty lustre, friable, the hardness = 2·5, the specific gravity = 2·2—2·3.

Pure rock-salt consists of simple chloride of sodium = Na Cl = 39·66 sodium, and 60·34 chlorine; the blue variety contains usually traces of copper, the red traces of oxide of iron, and the grey some bituminous clay or gypsum. The compact rock-salt, as it is given off in the mother-liquid which remains after the boiling of most brines, contains, moreover, either bromide or iodide of magnesium, or both, but only in small amount. The crepitating salt of Wieliczka, which, when thrown in water, gives out bubbles of gas with a crepitating or crackling noise, contains carburetted hydrogen with some carbonic oxide. Many kinds of red-coloured rock-salt contain numerous shells of small infusoria (*polygastrica loricata*), which tell of their marine origin. It is almost equally soluble in cold water and hot, and requires about three times its bulk to dissolve it; the solution has a purely salt taste, somewhat astringent, and gives, with nitrate of silver, a cheesy deposit of chloride of silver, which is insoluble in nitric acid. Before the blow-pipe it melts easily, and without noise, to a colourless pearl, which gradually evaporates, and colours the flame bright yellow; when melted with protoxide of copper and bi-sulphate of potash, or salt of phosphorus, a fine blue flame of chloride of copper appears on the charcoal. When sprinkled with sulphuric acid it gives off hydrochloric acid, which disappears with frothing even when cold, and still more so when sufficiently heated.

Rock-salt is the most widely diffused salt of sodium, and frequently constitutes very remarkable beds, or it fills up cavities, sometimes also blocks in layers, especially in the middle and later stratified rocks, where it generally accompanies anhydrite and gypsum, and is free from petrifactions. Sometimes, however, its presence can only be recognised in more or less rich bitterns or mineral springs. The beds of rock-salt of Wieliczka in Galicia are widely celebrated on account of their extent and purity. At Cardona in Spain a whole mountain of salt stands exposed to the air, in the western Kirgisen-steppe of Southern Russia, it lies only a few feet beneath the surface of the earth. The salt-beds of Swabia are found 20—40 yards deep in the lower shell-limestone in three different groups; those of Vic in Lothringen 58 metres deep in the lower lias, those of Chester 212 feet deep in variegated sandstone; the salt of Salzburg, Hall in the Tyrol, Reichenhall, Ischl, Hallein, etc., belongs to the so-called Hasselt mountains, a bituminous clay mixed with gypsum, which is put into Alpine limestone found there, and lixiviated underground. The saturated brine is then taken out and boiled down in the salt-pans. The salt-springs of Kreuznach, which are rich in iodine, rise in the carboniferous rocks, and are gradually concentrated before they are brought to the salt-pans.

There are extremely rich salt-springs at Kissingen and at Nauheim in the Wetterau; the latter are hot, and both are chiefly used as baths. The springs of Canstatt and Mergentheim in Swabia, also contain rock-salt.

The salt lakes of inland countries, as, for example, the Dead Sea, and also sea-water, contain a large quantity of salt, and the latter is frequently used for obtaining what is called sea-salt, as, for instance, on the coasts of Istria and Dalmatia.

When the brines of salt-springs are evaporated they form small, hollow, funnel-shaped, ladder-like crystals (Fig. 21), which sink into the soil, and are brought into the market as *kitchen-salt*. They always contain some water, and can only be freed from it by grinding and drying, or by melting it. In this way the greater part of kitchen-salt is prepared from the more impure kinds of rock-salt by solution and evaporation. A more simple method would perhaps be, to melt the rock-salt and allow it to trickle down, by which process it could be obtained in the desired shapes, and reduced to powder. Rock-salt is used principally for seasoning food and preserving meat, fish, etc., and has been so used from the earliest times. It also appears to be an indispensable element in the food of all animals, since all the fluids of the animal body contain more or less chloride of sodium. It is also much used as a manure. It is employed in the manufacture of soda, soap, and glass, and in the preparation of chlorine and hydrochloric acid in many manufactures. The red salt figured is also used for baths, in imitation of the natural springs, as a remedy in scrofula, glandular swellings, and the like.

Fig. 17.—Soda-Saltpetre, Nitrate of Soda.

The primary form is an obtuse rhombohedron of 106° 35′, similar to that of calcite, and as represented in Fig. 17; the cleavage is in the direction of the primary form, the crystals are colourless, of vitreous lustre, of 1·5—2·0 hardness and 2·09 specific gravity, transparent to translucent. It more frequently occurs in granular masses, similar to those of saltpetre. The chemical constituents are simple nitrate of soda = $\dot{N}a\,\ddot{\dot{N}}$, consisting of 36·75 parts of soda and 63·25 of nitric acid. The natural nitrate of soda of Chili contains, in addition to 94·291 of nitrate of soda, small quantities of chloride of sodium, sulphuret and nitrate of potash, nitrate of magnesia, iodide and bromide of magnesium and of water. It behaves like nitrate of potash before the blow-pipe and on charcoal, but it colours the flame yellow. The pure salt is soluble in three times its volume of water, and has a sharp, saline, and somewhat cooling taste. When it is sprinkled with sulphuric acid and heated, nitric acid vapours are given off.

Nitrate of soda is found in considerable masses in the district of Atakama in Chili, and is known in commerce as Indian or Chilian saltpetre. From a solution of this a tolerably pure soda-saltpetre can be obtained by crystallization; the crystals take the form of rhombohedral aggregations, with ladder-like hollowed planes, and, like potash-saltpetre, is much used in the preparation of nitric acid, but not for gunpowder.

Fig. 23.—Sulphate of Soda, Glauber Salts.

The primary form is an oblique rhombic prism of 99° 36′ and 80° 24′, which can only be split in the direction of the acute lateral edges. It is usually found only in crystalline grains or needles, or in mealy crusts. By solution and crystallisation, however, very large crystals, with truncation of the basal edges, angles, and lateral edges (Fig. 23), may be obtained, also twins and crystalline masses. Colourless, lustre vitreous, translucent, of uneven fracture, 1·5—2·0 hardness and 1·48 specific gravity. The elements of the pure salt are simple sulphate of soda, with ten equivalents of water; $\dot{N}a\,\ddot{S} + 10\,\dot{H}$, consisting of 19·2 soda, 24·8 sulphuric acid, and 56·0 of water. When native it is almost always rendered impure

by chloride of sodium, chloride of calcium, and carbonate of soda. It occurs very pure in the lower lias at Mühlecken in Aargau. In the air it falls to a white powder, from losing its water of crystallization. It is easily soluble in water, the solution has a disagreeable bitter-saline taste, and gives no precipitate with carbonate of potash, as is the case with Epsom salts, with which it sometimes occurs. Before the blow-pipe it melts easily, and colours the flame yellow; sulphuret of sodium is formed in the inner flame on charcoal. Its occurrence is very limited; in general it is found along with rock-salt, as, for example, in the Salzburg district, with Epsom salts at Saidschütz in Bohemia, and at Carlsbad.

Reussin is a mixture of glauber salts and sulphate of magnesia, and occurs at Sedlitz in Bohemia.

Bloedite consists of equal parts of sulphate of soda and sulphate of magnesia, with five equivalents of water, and is found at Ischl.

Glauberite, also klinorhombic, consists of equal quantities of sulphate of lime and sulphate of soda; it occurs in a crystalline state at Berchtesgaden, and Aussee in Austria, and in Spain.

Thenardite is anhydrous sulphate of soda; it crystallises in right rhombic prisms, gives off its water in the atmosphere, and then falls down to a powder. It is found at Salines d'Espartines, near Madrid.

Glauber salt is principally used in medicine. It is seldom prepared from the natural salts just mentioned, however, but is for the most part obtained as a secondary product; as, for example, from the remains of the manufacture of nitric acid, from Chilian saltpetre, or also from the bittern of many salt springs, in which it seems to be present from the decomposition of chloride of sodium by sulphate of lime.

Fig. 22.—Borax, Borate of Soda, Tincal.

This salt crystallises in oblique rhombic prisms of 86° 30′ and 93° 30′, with cleavage in the direction of the planes of truncation of all the lateral edges, so that an oblique rectangular prism readily arises. It occurs sometimes in its primary form, sometimes with truncation of the acute basal and lateral edges (Fig. 22), also as twins; forms which often present much similarity to those of common augite. Colourless, passing into grey and yellowish, but little lustrous, translucent, of 2·0—2·5 hardness, and 1·5—1·7 specific gravity. Readily soluble in water, and fine crystals may be obtained from the solution, which has a sweetish, somewhat alkaline taste. The elements are a bi-borate of soda, with 10 eq. of water $= \dot{N}a\ \ddot{B}^2 + 10\ \dot{H}$. It melts before the blow-pipe with great intumescence to a colourless glass, in which all metallic oxides and silicates are readily fused; and on this account borax is generally used in blow-pipe experiments. Borax is also used in solder, having the property of keeping the pieces of solder free from oxidisation, and of favouring the purification of smooth metallic surfaces. It is otherwise used as an ingredient in the manufacture of enamel and coloured glasses, the fusion of which it furthers. Purified borax is, however, generally used for this purpose. Of late years, much borax has been prepared from the natural boracic acid or *sassoline*, which occurs, collected in the salt-springs and small pools, at Sasso in Tuscany, and also in the Lipari Islands. It is hydrous boracic acid $= \ddot{B} + 3\ \dot{H}$. Sometimes rendered impure by sulphur gypsum and sulphate of manganese, and forms oblique rhomboidal laminæ, acicular crystals and scales, which feel unctuous to the touch, and have a cooling, acid taste. They are thus soluble in water and spirits of wine.

Borax is found on the shores of a salt lake in Thibet, in Persia and South America; the rough borax is also sometimes brought into commerce in crystalline masses and crusts. There are also combinations of borate of lime and borate of soda in different proportions, which are known as *borocalcite* and *boronatro-calcite*. Found with nitrate of soda at Iquique in Chili.

XI. SALTS OF MAGNESIA.

Figs. 18 and 19.—Boracite.

Boracite is borate of magnesia $= \dot{M}g^3\ \ddot{\ddot{B}}^4$, and crystallises in tetrahedrons like grey copper or fahlore (Plate XV. Figs. 18, 19, 20). It occurs more frequently in combination with the cube and rhombic dodecahedron (Fig. 18), so that the planes of the cube predominate, or else the tetrahedron is truncated at the edges (cube), and bevelled at the angles with three planes (pyramidal tetrahedron, Fig. 19). The small crystals have a vitreous to an adamantine lustre, the larger ones are usually dull, the colour is white, passing into grey and greenish; the small crystals only are transparent. The hardness is very considerable $= 7{\cdot}0$, the specific gravity 3. Insoluble in water. Before the blow-pipe it melts with evolution of air-bubbles to a crystalline-radiated pearl, and colours the flame green. It is found imbedded in the gypsum at Segeberg in Holstein, and in the limestone mountains at Lüneburg.

Fig. 24.—Epsomite, Sulphate of Magnesia, Epsom Salts.

The primary form is a right-rhombic prism, which occurs with truncation of the acute lateral edges, and of all the basal edges; sometimes with further truncation of the two vertical edges (Fig. 24), and more frequently still with hemihedral bevelling of the terminal planes, or in spear-like needles and long fibres. Colourless, lustre vitreous to adamantine, translucent to transparent; hardness 2·0, specific gravity 1·75. The elements are simple sulphate of magnesia, with 7 eq. water $= \dot{M}g\ \ddot{S} + 7\ \dot{H}$, composed of 18 of magnesia, 33 of sulphuric acid, and 48 of water. It does not effloresce in the atmosphere, and maintains its lustre; it is readily soluble in an equal volume of water. The solution has a bitter saline taste, and gives, with carbonate of potash, a white precipitate of carbonate of magnesia, which is soluble with effervescence in nitric

acid. It fuses readily before the blow-pipe, gives off water, and at last also sulphuric acid, leaving only pure magnesia. It occurs in Andalusia, Siberia, and North America, and more sparingly in Germany at Jena, Zellerfield, etc., and in Britain at Epsom in Surrey, and Hurlet in Renfrewshire. The bitter mineral springs of Saidschütz and Pilna contain epsomite in large quantity in solution, and it can be prepared from these waters. Most of the Epsom salt of commerce and medicine is prepared from the magnesian limestone of Yorkshire.

XII. SALTS OF AMMONIA.

Fig. 25.—Salts of Ammonia, Sal Ammoniac, Muriate of Ammonia.

This salt crystallises in regular octahedrons, cubes, and leucitoids; it frequently occurs also in twins with wedge-shaped distortion, globular, drusy, etc. Colourless or yellow, vitreous lustre, hardness 1·5 to 2·0, specific gravity 1·52. Volatilises in the matrass, and sublimes; burns quite away before the blow-pipe. That which is colourless is pure chloride of ammonium = NH^4 Cl; the yellow variety contains chloride of iron, and is therefore a so-called iron sal-ammoniac. It was formerly found very fine in many lavas of Vesuvius and Etna, and especially at the burning mountain at Duttweiler, as a product of the burning of stone-coal. Great masses of sal-ammoniac have also of late years occurred at some eruptions of Vesuvius, so that the gathering of it was profitable, and the inhabitants were in some measure compensated for their losses. When rubbed up with hot lime, it gives off ammonia; it is readily soluble in water, to which it imparts a sharp saline, somewhat piercing, taste. In the preparation of sal-ammoniac, cubes are sometimes obtained in the form of twins, as in Fig. 25. They are generally rendered impure by animal oil, and coloured brown, and in a section they present a beautiful six-rayed star. Most of the sal-ammoniac is now artificially prepared, and obtained as a secondary product in the manufacture of prussiate of potass from animal substances.

XIII. COMBUSTIBLE SUBSTANCES.

These are more or less easily set fire to, and are totally or partially consumed, while they take up the oxygen of the atmosphere and form liquid acids. Some of them are actual minerals, others, such as amber, and all kinds of coal, are derived from the vegetable kingdom. Others like the honey-stone, are compounds of an organic acid with an inorganic base; and with regard to others, such as the anthracites, it is doubtful whether they belong to the vegetable or to the animal world.

PLATE XII.

Figs. 1—3.—Sulphur.

Sulphur is a simple element, which principally occurs in volcanic districts, associated with gypsum; frequently also combined with metals which it mineralizes, not only in the igneous but also in the stratified rocks.

The natural or native sulphur has a rhombic octahedron for its primary form, and may be split in the direction of its planes, as well as in those of the rhombic prism. Besides the primary form, we find truncations of the vertical angles with bevelling of the newly-formed basal edges (Fig. 1); further truncations of the acute pyramidal, and of the basal edges combined with the two foregoing pyramids (Fig. 2), double and triple truncations of the same kind, as Fig. 3; also rhombic prisms and twins; single pairs of planes are frequently extended at the expense of the secondary planes, so that oblique forms arise; there are also compact, granular, earthy, and fibrous varieties. Sulphur is present in many fresh-water limestones in the South of France as a medium of petrifaction, where it fills the shells of *planorbes* and *paludines*, and has probably been deposited by sulphureous springs. Crystallised sulphur is citron yellow passing into reddish and grey, adamantine to resinous in lustre, transparent to translucent, of conchoidal uneven fracture, and strongly lustrous in the planes of fracture. The compact variety is yellow, grey, and even brown, frequently presents but little lustre, and is generally rendered impure by bitumen. The crystals are always harder (= 2·5) than the compact (= 1·5), the specific gravity is 2·0. If crystallised sulphur is heated in the hand, it often crepitates and makes numerous leaps, and takes on polar electricity. The chemical constitution is pure sulphur = S; it is sometimes, however, made impure by the pressure of bitumen, selenium, and arsenic. In the heated retort it melts readily at 226° Fahr., and crystallises on cooling in oblique rhombic prisms, which afterwards become opaque. When raised to a higher temperature, it becomes agitated and volatilises, and condenses on the cold part of the tube as a loose yellow powder (flour of sulphur). When heated for a long time and plunged into water, it forms a tough mass, which is plastic for a considerable period. It is insoluble in water and alcohols; it is soluble in bi-sulphate of carbon, and crystallises from the solution in rhombic octahedrons. Heated with nitric acid it forms sulphuric acid. In hot fatty oils it is also soluble, and in potash and soda ley. It is very inflammable in the atmosphere, and burns with a bluish flame, and gives off a suffocating vapour of sulphureous acid (S̈). If this gas is collected

and brought into contact with nitric acid, it is converted into sulphuric acid ($\ddot{S}$.)

The occurrence of native sulphur is limited to certain localities. The principal places are, Girgenti and Catalto in Sicily, Tolfa in the Papal States, and the Solfatara at Naples. In smaller quanties it is found at Bex in Maadt, at Hering in the Tyrol, at Cracow, etc. Small crystals have also been found in Derbyshire and in other parts of the north of England. The vapours of most volcanoes also contain sublimed sulphur, as for instance at Vesuvius, Etna, and Lipari. The sulphur of commerce is generally prepared by melting the native sulphur, and pouring it into round or quadrangular moulds. That of Great Britain is all derived from iron pyrites. It is used for making sulphuric acid, gunpowder, as material for lighting matches, and in medicine ; also for different chemical and technical purposes, for moulding, modelling, etc. The compounds of sulphur with the heavy metals, are called *glances* and *pyrites*, when they have a metallic lustre, as for instance lead, iron, and copper pyrites, and silver glance ; but if they are transparent and of adamantine lustre, they are known as *blendes*, such as cinnabar, zinc-blende, the silver-blendes, etc.

The sulphureous and sulphuric acids, and the sulphuric salts, form a more abundant series. The first are found in the vapours and waters of most volcanoes, and the others, namely, gypsum, anhydrate, the sulphates of baryta, and strontian, partly in layers, and partly in veins of rocks generally. Sulphuretted hydrogen is contained in the vapours of many volcanoes and in all sulphureous waters, and may be recognised by the smell, which resembles that of rotten eggs.

FIG. 4.—HONEY-STONE, MELLITE.

The primary form is a quadratic octahedron of 61° 46′, of the polar edges (Fig. 4). Besides the primary form we find also quadrilateral prisms combined with the octahedron, and truncation of the edges ; also twins and drusy aggregations. Wine yellow, passing into reddish and brown, translucent, hardness 2—2·5, and specific gravity = 1·58—1·66. The constituents are, 3 eq. mellitic acid ($C_4 O_3$) with 1 eq. alumina, and 15 eq. water. Before the blowpipe honey-stone becomes at first black, and then burns, leaving a deposit of white alumina, while the mellitic acid is changed into carbonic acid, and the water given off. In nitric acid it is perfectly soluble with solution of carbonic acid. It is found as a recent product in the brown coal at Artern at Thuringia, and at Bilin in Bohemia.

The *humboldtite*, or *oxalite*, which consists of oxalate of iron ($2\,\dot{F}e\,\ddot{C} + 3\,\dot{H}$), also occurs in the brown coal of Bilin, and the *struvite*, a phosphate of magnesia and ammonia, discovered in digging the foundation of St. Nicholas' church at Hamburg in 1845, in various crystals of the right-rhombic system, where it had apparently been formed from animal refuse, are both organic salts of a similar nature.

FIGS. 6 AND 7.—AMBER, SUCCINITE, BERNSTEIN.

Amber is a natural resin, which is found in the upper Tertiary and in the lower Diluvial formations of many districts, and is considered a product of the coniferæ, of which pieces of wood and bark are still found in it. It occurs in irregular masses, from the size of a pea to that of a man's hand, and larger, sometimes also in stalactites, or in long plates. Externally it is rough and unseemly, often encrusted with earthy and carbonaceous matters. It presents, however, a lustrous conchoidal fracture, with a remarkable waxy or resinous lustre, and is not unfrequently perfectly transparent (Fig. 6), or translucent (Fig. 7), and sometimes cloudy and milky. The friability is so slight that it may be turned, filed, and polished ; hardness = 2·0—2·5, the specific gravity = 1·0—1·1. When rubbed it acquires negative electricity, and indeed from its Greek name, *electron*, the word electricity is derived.

When brought near the flame, it melts and burns with a peculiar balsamic smell, and gives off acid vapours of succinic acid ; it burns with a yellow flame, and leaves a carbonaceous residue, which contains lime, clay, and silica. In a heated retort, it also yields succinic acid and the strongly smelling volatile oil of amber. The residue consists of a brown bituminous mass. By these products amber is easily distinguished from the similar resins of the vegetable kingdom, such as dammara, copal, and colophony. Only a small part of the amber is soluble in alcohol and ether. The proximate constituents of it are resin, volatile oil, succinic acid, and the above-mentioned earthy matters ; the ultimate elements are carbon, hydrogen, and oxygen, along with traces of nitrogen.

Amber was valued by the ancients on account of its electrical properties and for medicinal fumigation ; they were also aware of its organic origin, It frequently contains insects, ants, etc. (Fig. 6), and such pieces are highly valued if they are, at the same time, transparent. Several hundreds of such specimens are known ; they are, for the most part, wood-insects of the tropical and temperate zones, of the European and West Indian type. The bits of wood and bark occurring in amber belong to different species of pines, one of which has been called *pinus succinifer*.

Amber is principally found on the shores of the Baltic, between Königsberg and the coast of Pomerania, and is partly dug up and partly fished from the sea. More rarely it occurs in the tertiary clays and sands of inland countries, as in northern Germany, France, and still more rarely, in tertiary sandstone, as at Lemberg in Galicia (Fig. 7). It is occasionally found on the east coast of England, in sand in the neighbourhood of London, and in the Isle of Wight.

Perfectly pure pieces, which are fitted for cutting and polishing, are the most highly esteemed. They have been found of as much as ten pounds weight and more. The small, impure pieces are principally used for the manufacture of amber varnish and mellitic acid. Small transparent pieces are made into necklaces, bracelets, and other such ornaments ; larger bits are used for mouth-pieces for tobacco-pipes, and are valued at £8 and £10 per pound,—the milk-white specimens are particularly highly priced. The cutting is effected by leaden discs with tripoli earth ; chalk is used for polishing.

Asphaltes, mineral pitch or bitumen, cetinite, and elaterite, are all similar resins, having their origin in the vegetable kingdom.

By *asphaltum* is meant a blackish-brown, solid mineral pitch, of conchoidal fracture and small specific gravity, =1·1—1·2. The hardness varies from 1·5—2·0. It is soluble in oils, takes fire at a flame, melts and burns with a smoky flame, and diffusion of a peculiar tarry odour. The hard asphalte, reducible to powder, is found in large masses at the Dead Sea, and is from thence brought into commerce.

It is used as a black varnish or lacquer for leather and metals, as engravers' varnish, and for black sealing wax. The asphalt of Trinidad is softer, cannot be powdered, and when mixed with sand and small stones, it is used for paving dwelling-houses, terraces, footpaths, etc.

The asphalt of Val de Travers, in Neufchatel, and of Lobsann, in the Elsass, is yet softer; it is a peculiar bitumen, and occurs, generally mixed with sand and clay, in the upper tertiary formations. It is employed in Germany and France for the same purposes as above mentioned.

Retinite or resinite, is a yellowish-brown bitumen, of conchoidal resino-lustrous fracture, which is essentially distinguished from amber by its smaller degree of solidity, and its turpentine odour when heated. It occurs in the brown coal at Halle, at Meiersdorff in Lower Austria, and especially in Moravia; also at Bovey in Devonshire, and Cape Sable in Maryland, U. S.

Elaterite, also known as elastic bitumen or mineral caoutchouc, is a translucent, brownish-green, or dark-brown elastic resin, similar to softened caoutchouc, readily inflammable, burning with a clear flame, of 0·9—1·23 specific gravity, soluble in naphtha and ether, and it forms a solid carbo-hydrogen, according to the formula C H_2. In the atmosphere it becomes more solid and harder, it also loses its elasticity, and is then always found to contain a small quantity of oxygen, and sometimes nitrogen. It is found plentifully in the lead mines of Derbyshire, and sometimes at St. Bernard's Well, near Edinburgh.

Fossil wax, and various fats and oils, are also found in the mineral kingdom, especially in the neighbourhood of beds of brown coal, or as the products of distillation of stone and brown coals. *Ozokerite* is such a natural fossil wax, which is found at Slanick in Moldavia, and at Urpeth Colliery, near Newcastle-on-Tyne, and has the composition of elaterite. *Scheererite*, *fichtelite*, *hartite*, and *piancite*, are tallowy, paraffine-like carbo-hydrogen compounds of this kind. *Mineral naphtha* is a transparent, yellowish-white mineral oil, which swims on water, is extremely fluid, readily inflammable, and burns with a smoky flame. It occurs principally in Persia, and on the shores of the Caspian. It is used for dissolving India-rubber, and for preserving sodium and potassium, which have no action on it, as it contains no oxygen. *Petroleum and mineral tar* are thick fluid natural oils of this kind, containing more or less bitumen. They possess, for the most part, a repulsive tarry odour, are only partially soluble in pure alcohol, dry up in the atmosphere, and leave a black-brown pitchy mass, and on this account are used as varnishes for the manufacture of cement and mortar. The principal localities are Lobsann and Blâttelbroun in the Elsass, at the Tegernsee in Bavaria, and Haring in the Tyrol. The holy fire of the Parsees and fire-worshippers is nothing but naphtha vapours, which, having been set fire to, keep perpetually burning. Such places are enclosed for temples, and priests are appointed for maintaining the flame.

Carbons of the Mineral Kingdom—(Anthracite and Brown-Coal).

The carbon diffused throughout the mineral kingdom occurs in very varied forms. The purest carbon of octahedral form, and perfect transparency, is the diamond, as we have already seen, when treating of the precious stones. It, too, may be perfectly consumed by burning, leaving as a residue nothing but carbonic acid.

Graphite (black lead), is a carbon with a metallic lustre, which crystallises in hexagonal tables (Plate XII., Fig. 5), and double pyramids, but it occurs more frequently in scaly-foliated, or fine scaly masses, iron black, of a metallic lustre, giving off a grey colour on paper, soft and flexible. It has a greasy feel, a hardness of 1·0—2·0, and a specific gravity of 1·8—2·1. The constitution is pure carbon; sometimes, however, it is rendered impure by a little iron, lime, and alumina. Before the blow-pipe it burns with difficulty without melting, and is insoluble in the flux, also in acids, and is found principally in primary schistous rocks, sometimes also imbedded in lime and granite, in compact masses; in its purest condition at Borrowdale in Cumberland, where, however, it has been almost exhausted; also in Spain, at Passau in Bohemia, and North America. It occurs, moreover, at Bannerdale at Keswick, at New Cumnock, Ayrshire, near Huntly in Aberdeenshire, in the island of Mull, and other places in Scotland, and near Kilkenny in Ireland. It is principally used in the manufacture of lead-pencils, and is therefore a very valuable mineral; also for crucibles, for blackening cast-iron, as a coating to galvanoplastic models made from stearine, gutta-percha and the like; for strops, for lubricating parts of machinery, etc.; it is also employed in medicine.

Fig. 8.—Anthracite, Non-Bituminous Coal.

This mineral forms black, compact masses, sometimes coarse slaty pieces or tables of irregular, flat, conchoidal fracture, and of more or less brilliant metallic lustre, sometimes with a bluish play of colour (Plate XII., Fig. 8), and is distinguished from the stone-coals by greater hardness (= 2·0—2·5), and weight (= 1·8), by the difficulty of burning it, and especially because, when heated in close vessels, it neither yields olefiant gas nor oily products of distillation. It is a mineral coal, with an amount of carbon reaching as high as 96 per cent., so that, after incineration, an ash is left containing silica, alumina, and oxide of iron, but free from alkalis. Real anthracite is found in layers or beds, sometimes of remarkable thickness, especially in the greywacke and clay schists, as at Ebersdorf in Voigtland, and in Rhode Island, U.S., where the specimen figured (8), was obtained. It is mixed with other coals, being difficult of combustion by itself. It is used as fuel, and equals the best coals, with which it presents many points of similarity, the structure being excepted. The organic origin of anthracite is the less certain, since it generally occurs without being accompanied by vegetable remains.

Figs. 9 and 10.—Common Coal, Coal.

Quite black, more rarely brownish-black, perfectly opaque, irregularly formed masses, lustre resinous, friable, of more or less distinct slaty structure, not unfrequently occurring in rhomboidal fragments, of conchoidal to flat, pitchy-lustrous fracture, frequently capable of giving off its black colour; hardness = 2·0—2·5, specific gravity = 1·15—1·60. Combustible and readily inflammable, with a clear smoking flame, and development of a peculiar bituminous

odour. When heated in closed vessels it yields olefiant gas (carburetted hydrogen = $C_2 H_2$), empyreumatic oil and tar, also ammonia and watery vapour, and leaves a black, porous slag of metallic lustre, which is called burned coal or *coke*. Water, acids, and oil do not dissolve any part of it, but with sulphuret of carbon a small quantity of brown resin is given off. The composition generally is 70—80 per cent of carbon, 3—21 per cent of hydrogen, 2—7 per cent of nitrogen, 6—24 per cent of oxygen, so that it may be said that the coals of each district have a different composition. Thus a few, especially coarse and earthy coals, yield very little olefiant gas; on the other hand, others, such as the slaty and all cannel coals, give double and triple as much.

The following descriptions of coal are distinguished by their structure :—

1. *Slate-coal*, with distinctly foliated fracture, and a highly resinous lustre, sometimes tarnished in various colours, of 1·27—1·34 specific gravity. It is the most abundant kind of common coal, which is found especially where large beds of common coal occur, as at Ruhr, Saar in Silesia, Belgium, France, England, North America, and Australia. Fig. 10 represents a bit of slate-coal from Planitz in Saxony.

2. *Splint-coal.*—Compact, slightly lustrous, pitch-black, of a thick slaty structure and uneven fracture. It is found in subordinate beds sometimes with slate-coal, as, for instance, in Saxony, Moravia, and Silesia. It presents in the fracture a strong fatty lustre, so that it is also known popularly as pitch-coal. The specific gravity varies from 1·45—1·60.

3. *Parrot* or *Cannel-coal.*—Greyish or brownish-black, slightly lustrous, of flat conchoidal, almost even fracture, and compact slaty segregation; but slightly friable, and burns with a clear flame. It has the very low specific gravity of 1·21—1·27, and leaves as residue of combustion a loose coke. The principal localities for it are in England and Scotland, at Wigan in Lancashire, at Lesmahagow in Lanarkshire, and West Wemyss in Fife; it has lately been found near Saarbrück, as seen in Plate XII., Fig. 9. It is applied with great advantage to the manufacture of gas; it leaves, however, a small very porous coke, and loses about 44 per cent in weight. As it is extremely compact, and may be made into boxes, buttons, knife-handles, etc., it also takes on a very handsome polish. In burning, of all coals it leaves the smallest amount of ash, which sometimes only amounts to ½ per cent.

4. *Earthy Coal*, or *pulverulent coal*, *Russkohle* of German authors.—Greyish-black, pulverulent, dim or glimmering, readily giving off colour, easily inflammable, generally found in small layers between the slate-coals, and only exceptionally in separate beds, as at Ganitz. The fine powder, under the microscope, presents distinct cells and vessels, as they occur in the stems and leaves of the lower vascular plants; this structure is only partially destroyed by coking. Technically we distinguish between *caking coal*, *coking coal*, and *sandy coal*. The first comprises those coals which are easily melted aud leave a loose coke, the last such as are perfectly incapable of being melted and yield a brittle coke, while coking-coal is a compact, tough coal, which leaves the best coke. The splint-coal of Belgium yields 81, that of Essen on the Ruhr 79·5, that of Saarbrück 66, and the English cannel coal only 51·3 per cent of coke.

Common coal is not only highly valued for the manufacture of gas, but especially useful as fuel, for 100 pounds of it produce exactly as much heat as 230 pounds of dried wood; and indeed it may be said that the greater part of modern industry, and the application of steam-power to machinery, railways, and steam-boats, have only been made possible by the help of coal, so that it is now in extensive demand, and produced in great quantities. Luckily the coal-fields of many countries are so considerable, that many of them still possess a sufficient supply for a thousand years.

The geological occurrence of real common coal is limited to the older stratified rocks; the peculiar coal formation is confined to certain basins and cavities in the neighbourhood of the oldest stratified and primary rocks. Yet there are black coals in the course of the Alps, and in the middle and even in the upper stratified rocks, although in smaller quantity, which resemble the old slate coal.

Coal occurs generally in turn with slaty clay, containing vegetable remains, in layers, from a few inches to three and six, and exceptionally to as many as 30 feet in thickness, imbedded in the carboniferous sandstone. In Silesia and Saxony there are generally found only from 4—12 beds, in England 12—40, in the Saarbrück 60—170, in Belgium as many as 200—300 beds, with a total thickness of 50—375 feet. In North America, the greatest coal-field extends over Pennsylvania, Ohio, and Virginia, with a surface of 2500 German square miles; there are 10—15 seams, from 8—50 feet thick, of the finest coal. In Illinois and Michigan there are also extensive coal-fields, and it has been reckoned that the total superficial area of the coal formation, in the twelve principal coal states alone, amounts to 133,132 square miles, or a quarter of their entire area; the Pennsylvanian bed alone has an area of 15,437 square miles, or one-third of its entire area. The coal land in Great Britain and Ireland has an area of 11,859 square miles, or about one-tenth of the whole surface. In the year 1855 the total produce of coal in this country amounted to 64,453,070 tons, whereof 4,760,000 tons were exported. The smelting of iron annually consumes about 10,000,000 tons of coal, or nearly four tons of coal for every one of iron produced. Extensive coal-beds have also of late years been found in the East Indies and Australia, in Borneo, Sumatra, and the Celebes.

Jet.

This name is applied to a compact, highly lustrous coal, of a perfectly black to a pitch-black colour, with a fracture of resinous lustre, and sometimes with a distinct wood-like structure. It is perfectly compact, and difficult to work, of 1·29—1·35 specific gravity, and 2·0 to 2·5 hardness, capable of polish, and burns a long time without smell, leaving only from 2—3 per cent. of ash. It is principally formed in the lias and tertiary formations, and it is used partly for fuel, and partly for the manufacture of small objects of art and ornament. It occurs most abundantly in this country at Whitby, in Yorkshire, where the value of the jet manufactured in 1855 amounted to £20,000.

Figs. 11—13.—Brown Coal, Lignite.

Brown coal is the name generally applied to the coals

of the more recent stratified formations, of a predominating brown colour, in which the organic structure is usually distinctly apparent. Some of these resemble peat, others consist of stems of wood (Fig. 13), leaves of trees or fruits (Fig. 12), half converted into coal; others, again, like needle-coal of Lobsann, in Elsass (Fig. 11), are evidently woody and vascular bundles of palm-stems converted into coal. In many districts, as, for example, Saulzhausen, in the Wetterau, whole series of fossil leaves and fruits are met with, and enclose freshwater fish; others have mosses, insects, etc. Stems, leaves, and cones of firs and pines are found in great abundance at Uznach, on Lake Zurich, and at Käpfnach carbonised teeth and bones of the rhinoceros (*R. incisivus*) have been found. Woody-fibrous brown-coal, the so-called *lignite*, is the most abundant. It is formed partly of pines and partly of other trees. The name of *clay-coal* has been given to a slaty, slightly lustrous coal, mixed with bituminous clay, which occurs in the lower keuper, in Swabia. It is interesting chiefly as often containing fossil ferns and calamites, fresh-water shells (*anodonta*), and reptiles, and it is frequently so penetrated by pyrites as to give off green vitriol and alum on decomposition. *Paper-coal* is a finely foliated, flexible brown-coal, sometimes not unlike brown pasteboard, easily set on fire, and combustible. It is found among the other brown-coals at Bonn on the Rhine. *Moor-coal* is the name of a compact, slightly-lustrous variety of brown-coal, of low specific gravity, in which organic structure can only be discovered by the help of the microscope. It takes fire readily, and burns well. It is sometimes light-brown, resembling umber or brown earth, and is found especially at the Westerwald, in Moravia and Hesse. *Earthy-coal* and *Cologne-umber* are earthy-brown-coals, more or less mixed with clay; the latter is dug in the Cologne district, and, when washed, worked into conical forms, and dried, it is brought into the market as a colouring material.

Peat.

Peat is a combustible substance of more recent origin, not unlike brown coal, which is frequently found in considerable quantity in the wet lands of different districts, and is often produced under our eyes. This is the case especially in such places as have a marshy soil, or are continually kept wet, and covered with a corresponding vegetation, or *peat-bogs*. A substratum of clay or of compact rock, impervious to water, and an inclination of the soil so slight as to afford no exit to the water, are the necessary conditions, and they are found in the low ground of the valleys and extensive plains, as well as on the ridges of many mountains. The plants which are favourable to formation of peat must have the peculiarity of dying off from below upwards, and of growing at the top; to these belong, for example, many sedges (*carex cæspitosa, filiformis, chordorrhiza*), the cotton grasses (*Eriophorum vaginatum, capitatum, latifolium*), some willows (*salix repens, rosmarinifolia*), the mosses (*Sphagnum, polytrichum*, etc.), and the like. The dead stems, roots, and leaves, are gradually changed under the influence of water into a mouldy-looking substance resembling brown coal, in which the cells and bundles of vessels of the plants comprising it can still be recognised. The places of their occurrence are called *peat-bogs*, and, according to the different localities, meadow or marsh peat. Peat usually forms regular layers, which are sometimes separated by a layer of clay or sand, and, according to their age, may reach a thickness of from a few feet to fifty or more. Peat-bogs of this depth, and of great extent, are found sometimes in the plains of Northern Germany, and in the flat land of Upper Swabia and Bavaria. The bogs of Ireland are estimated to cover 3,000,000 acres of land. Many of them bear witness to their ancient origin by including animal remains of the diluvial period, as, for instance, gigantic deers, ure-oxen, and various tortoises, etc., and are therefore called diluvial peat, while, on the other hand, the newly forming bogs enclose only remains of animals of the present period, and frequently, also, traces of human industry. To the geologist peat is interesting in many ways, because it best explains the origin of brown, and common coal. It is also very valuable as fuel, and in many cases it can take the place of coal and wood. The ashes contain as little alkaline matter as that of the common and brown coal. The heat given out by turf is about one half that of coal. Attention has of late years been directed to the various chemical compounds which may be obtained from peat, and various plans for obtaining them proposed. In the great exhibition of 1851, no less than seventeen different compounds were exhibited as extracted by Stone's process, among the more remarkable of which were, ammoniacal liquor, peatole, paraffine, sulphuretted peat-charcoal, chloroform, and tar.

XIV. HEAVY METALS, METALLIC MINERALS OR ORES.

The heavy metals are distinguished from the lighter metals of the alkalis and earths, and from the metalloids, by their greater atomic weight (= 5—24), by their more ready conversion into a metallic condition, their opaqueness and metallic lustre, hardness, etc., and by their lower affinity for oxygen. They are found either native or as alloys, that is, in combination with other metals, or mineralised by sulphur, selenium, bromine, chlorine, or oxygen; the combinations with the last mentioned are called oxides, and they have either the peculiarities of a base, or of an acid, or sometimes of the one, sometimes of the other, or of a neutral oxide. Combinations of metallic bases with metallic or other bases are also found. The metals are, in a general way, divided into *noble* and *common metals*; and under noble are comprised such as have little affinity for oxygen, and give it off by simple heating, and for this reason are easily separated from their combinations, and retain their lustre in the atmosphere. To this class belong gold, platinum, silver, paladium rhodium, iridium, and ruthenium; others which have some of these peculiarities, such as mercury, nickel, and copper, have been called *semi-noble*. The *common* metals include all

the other heavy metals. Scientifically they have been divided according to their physico-chemical properties into *electro-positive* and *electro-negative* bodies. Among the electro-negative class, tellurium, arsenic, and antimony, are found nearest to the series of metalloids, inasmuch as they mineralise other metals, like sulphur, selenium, etc.; those principally forming acids are, chromium, molybdenum, vanadium, tungsten, tantalum, pelopium, niobium, titanium, and osmium; to the positive class belong, in addition to the precious metals, mercury, copper, uranium, bismuth, lead, cerium, lanthanum, cobalt, nickel, iron, cadmium, and zinc; the last is the most positively electric, and thus is associated with the light metals of the earths (yttrium, zirconium, aluminum, glucinum, and magnesium), and also to those of the alkalis (calcium, strontium, barium, lithium, sodium, and potassium), of which the last is the most positive of all. As the metals just mentioned are not all of equal importance, in what follows we limit ourselves to the most important of these, and refer the reader to the larger hand-books and treatises on mineralogy and chemistry.

The metals have from the earliest times attracted the eyes of man by their lustre, hardness, ductibility, malleability, fusibility, and durability, and this was especially the case with those which occur native, especially gold, silver, and copper, while platinum (and the other platinum metals) was first found, since the discovery of South America, by Ulloa in the year 1735, and recognised as a proper precious metal by Scheffer in 1752. Iron has also been long known not only to the Israelites and Asiatic nations, as is clearly proved by a passage in the Old Testament, but it appears that the metallic lustre of the magnetic iron-stone, of such frequent occurrence in the East and in the interior of Africa, and perhaps also of the specular iron, had early induced the inhabitants to endeavour to melt it by means of wood or coal, and so to produce a more or less malleable rod-iron. Mercury and tin also, as well as the bronze-like copper alloys, have been long known to man, as the writings of the ancients testify. It also appears that these metals were principally introduced into commerce by the Phœnicians. The influence now exerted by the metals in the arts and sciences, and on commerce, is generally known; and in order to give a slight notion of the great importance of the metals, we need only allude to the various applications of iron to instruments and machinery of all kinds, to the employment of silver and gold in coining and in traffic by exchange, as well as for ornament of every variety; moreover, to the applications of platinum to chemical and physical apparatus, of mercury and antimony in medicine, of cobalt, chrome, uranium, and lead, to the manufacture of colours, for enamel, and other purposes; of antimony, lead, and tin in the manufacture of printing-types, of copper to electro-plating, and of steel and copper to the production of steel and copper plates for engraving.

In the crust of the earth the heavy metals play a subordinate part in comparison with the light metals of the earths and alkalis, especially with alum, calcium, and sodium; and iron alone, the most useful and at the sametime the most harmless, is generally diffused, it is for the most part accompanied by a small quantity of manganese, while the others only appear subordinately, mineralised in veins and beds, sometimes disseminated, and are obtained with great labour from a considerable depth. Gold and platinum seem to be exceptions, in so far as they are also found, the former often in large quantites, in wet land; and in a few places, as, for instance, in North America, copper appears on the surface, and silver in Peru. The native iron, which occurs here and there on the surface of the earth, is generally meteoric iron, and does not come into the same category.

I. NOBLE OR PRECIOUS METALS.

PLATE XIII.

Fig. 1—7.—Gold, Native Gold.

One of the longest known metals, which has been always highly valued on account of its fine colour, malleability, capability of polish, and ductility. It is the only yellow metal which occurs native, and by its malleability is easily distinguished from the few yellow ores which occur, namely, copper, iron, and nickel pyrites. It occurs almost always native; it is, however, always mixed with more or less silver, which takes away from its specific gravity as well as from its colour, the deep-yellow becoming lighter. Native silver also always contains a small amount of gold.

Native gold occurs crystallized, in cubes, octahedrons (Fig. 2), combinations of the cube with octahedron and dodecahedron (Fig. 3), or in crystalline foliated masses (Fig. 4), most frequently in compact roundish grains, imbedded in, or aggregated on a finely granular reddish quartz, as, for instance, in California (Fig. 1) and Australia (Fig. 9). Still more frequently it is found in alluvial deposits in the form of a finely foliated powder as gold dust, like Fig. 8, or in variously-shaped flat grains, which, by rubbing on the sand, often have a polished appearance, like Fig. 7; both of these occur in California; or also in long, flat lumps, with a rough upper surface, like Fig. 6, which is from the alluvium of the Gold Coast. The larger lumps, or *nuggets*, of rounded forms, are exceptions, as represented on a reduced scale in Fig. 5. This remarkable specimen was found in Victoria in the year 1852, and weighed 27 pounds 6 ounces. It was 11 inches long and 5 thick, and it had the appearance of an oblong melted mass. A still larger lump was found in California in 1855; it weighed $160\frac{1}{2}$ pounds, and was mixed with quartz, which weighed about 15 pounds. It was sold for 40,000 dollars. In the alluvium of the Urals pieces of 27 and 87 pounds have been found, and very considerable masses at Conception in Chili. That gold was in earlier times also found in much greater quatity in Asia and Africa is testified, among other things, by the description in holy writ of the building of Solomon's temple, and of the immense masses which were

brought to him as presents (2d Chronicles, chap. i. 15, chap. iv. and v., chap. ix. 13, where it is stated that the whole of the gold which was brought to Solomon in one year was 666 talents, and in verse 14, that all the kings of Arabia, and the governors of the land, brought gold and silver as presents).

Native gold is of a deep yellow colour, with a high degree of metallic lustre, and gives a brownish-yellow streak on the touchstone, which is not acted on by nitric acid; it approaches more to silver-white, however, as the gold contains more or less silver. The amount of silver contained varies from 1—10 per cent. and more, and is not constant; that from the Urals and South America contains, on an average, 98, the Australian 95, and the Californian 90—93 per cent. of gold. The silver-gold or *electrum* of Schlangenberg in Siberia contains 36; that of Börospatak in Siebenbürgen 38¾; the golden silver of Kongsberg as much as 72 per cent. of silver; besides, there are generally traces of copper and iron, sometimes also of platinum and gold. The hardness is = 2·5—3·0, and rises somewhat with the amount of silver; while, at the same time, the specific gravity falls, since from 19·4 it sinks down to 12·6. The former of these weights is that of fine beaten gold.

Gold is malleable in a very high degree; so much so, that a single grain may be beaten out to 56¾ square inches. This gold-leaf, which is principally used for gilding wood, metal, paper, etc., is by transmitted light somewhat translucent, and presents a sea-green colour. In the fracture gold is hacked and uneven; the structure generally appears to be perfectly compact.

Gold is found usually associated with granular quartz, sometimes along with iron and copper pyrites, in veins of the primitive rocks; as, for instance, at Salzburg, in Dauphinée, in some parts of the Central Alps, at Bersowsk in the Urals, and in the United States of America, in the syenitic porphyry on the south-east of the Carpathians. In more recent formations it occurs sometimes with quartz, in Siebenbürgen and Hungary, principally in combination with telluric ore. In Brazil it is found in iron-micaceous schist. Gold is, however, generally found in clayey sand, containing more or less iron, in wet districts, in the so-called gold buddles, but, in this case, it is also usually accompanied by grains of quartz. The gold alluviums known up to the present time are those at Caschmir in Persia, on the Upper Indus, in Borneo, Celebes, and Sumatra, in Asia; in the districts of the origin of the Upper Nile, at Senegal and Gambia, in Africa; in California in the Sacramento territory; in the rest of the United States; in Georgia, Virginia, North and South Carolina; in Brazil, especially in the districts of Minas-Geraes, and in the neighbourhood of Bahia. In the district of the Cordilleras gold is found in the veins and sands of Lima, Peru, and Chili. In Australia the gold alluviums seem unlimited, and the provinces of Victoria and Sydney especially have already, within a few years, yielded an amount of gold which exceeds that of California. Many sand-stones also of the lias and tertiary formations contain traces of gold, and many streams in France and Germany, especially the Rhone and Garonne, the Moselle and the Rhine, the Iser and the Danube, yield a small quantity of gold. Gold has also recently been discovered in considerable quantity on Fraser's River, Vancouver's Island, and immense numbers of miners are being attracted thither. Recent accounts—(*Times' Correspondent*, 21st August 1856)—report that, wherever the bed of the river has been worked, gold in abundance has been obtained, and that nearly all the miners concur in the opinion that gold exists in remunerative quantities. The same account announces the discovery of silver in the interior, of which the ore is said to be abundant, and that lead ore is also found on the island.

Gold is used for all kinds of objects of art and ornament, for plate, and especially as coinage, and a medium of exchange. It is always alloyed with a small quantity of copper or silver, or of both, in order to give it hardness and durability; the beauty of its colour is, however, damaged by the process. The value of gold is usually calculated by that of silver, 14 to 15½ parts of this metal by weight being equal to one part by weight of gold; and its present price in bars is about £3 per oz, the mint or standard price is £3 : 17 : 10½. In the working of gold the amount of silver contained is taken into consideration as well as the value of the work, and the material is taxed according to the caratage. Gold of 24 carats is said to be quite pure gold; that of 23 carats consists of 23 parts of gold and 1 part of copper or silver. The gold which is most worked is of 16—18 carats; that of the gold coinage of 22 to 23½ carats. If the alloy contains silver only, it is called the white alloy; if it contains copper, the red; and if both silver and copper are contained, it is called the mixed alloy. The last gives the best colour, and the goldsmiths know by experience that it imparts to their work a remarkably fine colour.

The average minimum price for the years 1844—56, in Frankfort on the Maine, was 375½ florins (a florin = 1/8d.), the highest 380½ florins, per mark (= 8 oz.), so that at the minimum it has 15⅓ times, and at the maximum 15½ times the value of silver.

At the Paris Bourse a kilogramme (= 2 lbs. 8 oz. 3 dwts. 2 grs.) of fine gold is rated at 3437 francs 77 cents, and valued according to the current rate of exchange; in 1846 it was as 15·44, and in 1856 as 15·54, to the price of silver in bars.

In London, from	1831—40,	the proportion was	=	15·75
„ „	1841—50,	„ „	=	15·83
„ „	1851—55,	„ „	=	15·42

The produce of gold has increased at least tenfold within the last fifty years, as will be seen from the following table of comparison:—

	YIELD OF GOLD.			
In Russia, anno 1800,	1,440 pounds	—1853	64,000	pounds.
„ Austria, „	3,400 „	„	5,700	„
„ the rest of Europe,	100 „	„	100	„
„ south of Asia, „	10,000 „	„	25,000	„
„ Africa, „	660 „	„	4,000	„
„ Australia, „	0 „	„	210,000	„
„ S. America & Mexico,	38,400 „	„	34,000	„
„ California, „	0 „	„	252,000	„
„ rest of United States,	0 „	„	2,300	„
	54,000 pounds.		598,100	pounds.

In 1 cubic metre (= 39 inches) of Rhine sand, as it is used for washing between Basil and Mannheim, are contained 0·014 to 1·01 grains of gold, so that the cubic foot contains only $\frac{1}{150}$—½ grain of gold. The gold sand of

Siberia and California is unequally rich; in the usual method of washing, however, there is always a great deal lost. Lately, a great part of the Californian gold has been obtained from the auriferous quartz, which is dug, and then crushed and washed by machinery,

The following are the chemical relations of gold. It is not attacked by any single acid; it is, however, easily solved by nitro-hydrochloric acid, and may be precipitated from the solution by the addition of copper or sulphate of iron. The solutions are used for galvanic gilding. Before the blow-pipe small granules may be melted without being changed; if the gold contains silver, as it usually does, it imparts to the salt of phosphorus pearl an opalescent cloudiness on cooling. If the gold contains 80 per cent. of gold or upwards, the latter may be quite separated by boiling with nitric or sulphuric acid; when it contains the silver in smaller quantities, the gold retains a part of the silver, so that it cannot be quite separated from it; such assays must therefore first be melted with a corresponding quantity of silver, in order to separate the latter from the gold, and the nitric acid must also be perfectly free from chlorine. Besides the gold which contains silver, there are also palladium, rhodium, bismuth, mercury, and tellurium golds, which must, however, be considered as rarities.

The principal telluric ores containing gold are the schrift-ertz, or graphic tellurium, and the white telluric ore.

The *schrift-ertz*, or *graphic tellurium*, crystallises in small right rhombic prisms, which generally occur disseminated and aggregated in small bundles and spear-like needles (Fig. 10). These bundles are of a light steel-grey, inclining to silver-white, of a brilliant metallic lustre and uneven fracture, sometimes with a variously-coloured tarnish, of 1·5 to 2·0 hardness, so that it soils paper, and is of 8·28 specific gravity. The composition is 60 of tellurium, 30 of gold, and 10 of silver. Formula, $Ag\ Te + 2\ Au\ Te^3$, it is therefore a combination of 1 eq. simple telluret of silver with 2 of tri-telluret of gold. Before the blowpipe it melts readily, the tellurium volatilizing as telluric acid, and at last a grain of gold, containing silver, remains on the charcoal. It is found with foliated tellurium at Offenburg in the porphyritic clay.

White telluric ore, which occurs in small rhombic prisms and netted crystalline-foliated aggregations, is almost silver-white, and contains, in addition to telluric silver and gold, a small amount of telluric lead and antimony. It is also preserved for silver and gold, and is found at Nagyag in Siebenburg.

The *native tellurium* of Facebay also contains from 2 to 3½ per cent. of gold. The *foliated tellurium*, which crystallises in square tables, consists of telluret of lead and a small quantity of telluret of gold, with 9·0—9·11 of gold. It is of a lead-grey colour, and is also found at Nagyag.

Fig. 11—13. Platinum.

Platinum was first discovered by Ulloa, a Spaniard, in 1735, in the river Pinto in Choco, near Popayan, and was called platinia, or silver-like gold, and was recognised by the Swedish chemist Scheffer, in 1752, as a new metal. It occurs native only in small, flat, roundish grains of metallic lustre (Fig. 11), especially in Brazil, from whence the specimens figured are derived; more rarely, it is found in larger pieces, with rough, uneven upper surfaces, or somewhat worn by attrition on one side (Fig. 12); the hollows in it appear blackish-grey, from being covered with irite; sometimes single cubic planes are seen, and small cubes are said to have been found at the Urals. Still more unfrequently, it occurs in larger pieces of from 2 to 20 pounds, and even larger. Fig. 13 represents such a piece of 2 pounds weight, which, like Fig. 12, is also from the Urals, in the district of Nischni-Tagilsk, 15 miles north from Katherinenburg. In Columbia larger pieces, from a single ounce to a pound and a half, occur only rarely.

Rough platinum has an iron-grey colour, inclining to silver-white, a moderate metallic lustre, a hardness of 5—6, and a specific gravity of 17·5—18; before the plow-pipe it is infusible, and is soluble in nitro-hydrochloric acid; a residue, however, of osmium, iridium, rhodium, palladium, and ruthenium, is always left; it generally contains, in addition to these, a small amount of iron, which varies from 2 to 13 per cent. The solution is yellow, and is precipitated by sal-ammoniac; the deposit is a double chloride of ammonium and platinum, and when heated leaves the platinum in the form of a very fine powder, which exhibits a certain amount of cohesion, and is known as *spongy platinum*. This is by repeated heating, hammering, and pressing, brought into the desired forms, plates, wires, etc., and is used for the manufacture of various instruments and apparatus which of late have executed a powerful influence in physics and chemistry. Pure platinum has a specific gravity of 21·0—21·7, and the spongy platinum may weigh as much as 26·0.

As to the mother-mineral of platinum we are not yet quite certain; that from Columbia appears to spring from the green-stone, that from the Urals from the serpentine; platinum has also been found in California, in the island of Borneo, and in the gold sands of Ava, as well as at St. Domingo, and in North Carolina.

Platinum containing iron with 11—14·6 per cent. of iron, and iron containing platinum with 8·15 per cent. of platinum, is found in the gold sands of Kuschwa. Platinum-iridium, with 55·44 of platinum and 27·99 of iridium, containing a small quantity of rhodium, copper, iron, and palladium, of 16·94 specific gravity, has been found in the platinum-sand of Brazil. The value of rough platinum is three or four times that of silver, of pure and manufactured platinum, about eight times.

Platinum has been long applied to the coinage and to medals in Russia; this use of it has, however, been discontinued. At present it is only used for wires, plates, crucibles, cups, distillation vessels, and galvanic apparatus; it is, however, indispensible for many purposes, in which its infusibility, combined with its great ductility and durability, as well as its indifferent relation to simple acids, are of remarkable value. Spongy platinum is used for producing lights, and, on account of its catalytic properties, for bringing about chemical combinations and the like.

Iridium.

One of the many metals which usually occur with platinum, and frequently render it impure. It was discovered in 1803 by Tennant.

Native iridium is found in silver-white grains, which

are generally a combination of the cube with the octahedron, and may be split in the direction of the planes of the cube. It is the hardest and heaviest of all metals occurring in nature, and has a hardness of 6—7, a specific gravity of 21·101—24·95; it is neither soluble by nitric acid nor by nitro-hydrochloric acid, so that in a platinum solution it remains with the osm-iridium, from which it may be distinguished, in addition to its greater heaviness, by the form of the grains, since the latter ore always occurs in hexagonal tables and bluish-white laminæ, with distinctly foliated fracture. When melted with saltpetre it is partially dissolved in hot hydrochloric acid, forming with it a blue fluid. Before the blow-pipe it evolves no odour of osmium like the following mineral. It has, until the present time, only been found at Nischni-Tagilsk, and at Ava in Lower India; the Ural variety contains 76·80 of iridium, 19·64 of platinum, 0·89 of palladium, and 1·78 of copper.

Osm-iridium is found in hexagonal laminæ and in thin leaves of a silver-white colour passing into bluish (Plate XIII. Fig. 14), and may be recognised by the foliated structure; the specific gravity is = 19·47—21·2, the hardness 6·0—7. There is a purer and a darker variety; the latter is distinguished by its more leaden-grey colour, and the greater amount of osmium it contains. Both of them, when held in the platinum forceps, give off the peculiar odour of the osmium vapours, which is especially marked in the darker variety. Both are insoluble in nitro-hydrochloric acid. Pure iridium has been applied to different metals as an alloy, especially to the improvement of steel, which is thereby made less liable to rust.

Palladium.

This precious metal is almost silver-white, and occurs in cubes, octahedrons, and small roundish grains of fibrous structure, as in Brazil, where it is found in the sand with platinum. It is also found in hexagonal laminæ, imbedded in the seleniurets of lead at Tilkerode in the Hartz; it is, therefore, dimorphous. The Brazilian variety always contains a small proportion of iridium and platinum. Its lustre is metallic, it is extremely malleable, of 4·5—5 hardness, and 11·5—11·8 specific gravity. The colour is somewhat lighter than that of platinum. In nitric acid with difficulty, and in nitro-muriatic acid easily soluble, to a reddish-brown fluid. When mixed with a solution of iodine it becomes black, and when held in the alcoholic flame it forms a blackish carburet of palladium. Before the blow-pipe it is infusible.

Palladium is generally obtained from rough platinum, and usually comes into commerce alloyed with a small proportion of gold. It has been applied to the manufacture of nautical instruments, and, when alloyed with gold and silver, for sockets for the pivots of watch wheels.

Silver.

A very widely distributed noble metal, sometimes occurring in large masses, which, by its pure white colour, malleability, sound, and high capability of polish, has been highly valued in all ages. It has, nevertheless, the peculiarity of becoming gradually tarnished or dull in the atmosphere, since it is decomposed by sulphuretted hydrogen, which is never absent where animal life exists. It is distinguished from the other noble metals principally by the manner of its occurrence; for it is found, not only native and alloyed, in combination with chlorine, bromine, iodine, etc., but also frequently mineralised by sulphur. It has no hydrogen compounds. Its combinations with the electro-negative metals, as antimony, arsenic, and tellurium, are especially remarkable, and they not unfrequently occur like sulphur compounds with a metallic lustre and friability. Most of the silver ores occur in the primary and the older stratified rocks, principally in veins; and large quantities of silver are obtained from lead-glance, in which it exists as a sulphuret of silver. It does not occur in alluvial deposits.

PLATE XIV.

Fig. 1—5.—Native Silver.

One of the most valuable varieties, for it sometimes appears in considerable masses. It occurs crystallised in cubes (Figs. 2 and 3; Fig. 3 represents the foliated structure in the direction of the cubic planes), in octahedrons, dodecahedrons, etc., stem-like, as in Fig. 1; in crystalline, often-streaked plates, as Fig. 4; arborescent, as Fig. 5; wire-like and capillary, and also in thick unshapely masses, especially associated with cobalt and lead ores, and sometimes with the ores of copper and nickel; it is either silver-white, as in Figs. 1, 2, and 3, or with a reddish tarnish, as in Fig. 4; or with a blackish tarnish, as in Fig. 5; sometimes entirely coated with sulphuret of silver and blackened, as, for instance, in the rocks of Saxony. The fracture is hacked, the metallic lustre, especially in the streak, is a remarkable silver-white; very malleable, hardness 2·5—3·0, specific gravity 10·3—10·8. Native silver consists either of pure silver, or it contains traces of gold, copper, arsenic, antimony, and sometimes even of platinum. Before the blow-pipe it is fusible without being changed. In pure nitric acid it is easily dissolved, the gold being left as a residue; the solution blackens the skin, and the silver is precipitated by copper as a metal; a solution of common salt, and free hydrochloric acid, give a white cheesy precipitate of chloride of silver when added to this solution.

The occurrence of native silver is principally confined to veins in the igneous and transition rocks. At one time a large quantity of silver was found in the Black Forest, in the Sophia mines at Wittichen, at Wenzel near Wolfach, and St. Antoine; also in the Reinerzau. The delicate little tree (Fig. 5), which consists of small octahedrons, and lies on reddish heavy spar, is from Heinrichsgang at Wolfach. It is found in great plenty on the Erzgebirge, at Freiberg and Schneeberg, and at Kongsberg in Norway, from whence the specimens Fig. 1—4 come, and where, in the year 1834, a mass of 720 pounds was found. In the year 1477 a block of 40,000 pounds weight was taken from the Markus mine

at Schneeberg, which was 6 feet broad and 12 long, and on which Augustus, then Elector of Saxony, is said to have dined. The Cordilleras of Peru and Chili have also produced immense masses of silver; and in the year 1803 the mines of Mexico alone yielded 2,340,000 marks; those of Peru 600,000 marks. In Chili the silver veins of Copiapo, in 1850, yielded 335,000 marks. In earlier times, Spain, too, had very rich silver mines; and, according to the testimony of the Scriptures, Asia must also have been rich in this metal. The price of silver is generally officially fixed, and the fine mark of 8 oz. valued at from 48s. to 50s. The application of silver to articles of furniture and luxury, to ornamental and artistic purposes, especially to embossed and chased work, to wire, plates, and silver-foil, to silvering and plating, as well as to coinage, is well known. It is generally, for these purposes, alloyed with copper.

The alloying with copper renders the silver harder, and, consequently, less subject to wear; nevertheless, coins, and articles of furniture, by being used, are gradually much worn, and there is thus an annual loss of a large quantity of silver. Blackened silver-wares may be again blanched by boiling them in a solution of cream of tartar and common salt, or in a solution of borax, if they are immersed in a perforated zinc vessel; and the polish may be restored by means of wet chalk or prepared hartshorn.

Fig. 6—8.—Antimonial Silver.

A silver-white silver ore, frequently tarnished yellow or black, slightly friable, which occurs in right rhombic prisms, like Fig. 7, of distinctly foliated fracture, or in hexagonal prisms, arising from truncation of the acute lateral edges, like Fig. 6; also in foliated masses, or granular, like Fig. 8, with a hardness of 3·5, and a specific gravity of 9·4—9·82. It melts on the charcoal, and tarnishes it with a white antimonial smoke, which may be easily blown off; at last there remains only a pure, malleable grain of silver. The crystallised and foliated varieties, as well as the coarsely granular antimonial silver of St. Wenzel in the Black Forest, where it formerly occurred in great richness, consist of 76 parts of silver, and 24 of antimony; and therefore have the formula, Ag_2 Sb. The finely granular variety, from the same place, contains 84 of silver and 16 of antimony, and is therefore Ag_3 Sb. This rare ore is now only found near Andreasberg in the Hartz, and at Allemont in France.

The *arseniuret of silver*, of scaly foliated structure, contains from 8—13 per cent of silver, besides iron, arsenic, and antimony, and is found in the Samson mines, near Andreasberg.

The *telluret of silver* may have a rhombohedral crystallization, but occurs principally in granular, lead-grey masses, with metallic lustre, and a hardness of from 2·5 to 3, and a specific gravity of from 8·4 to 8·83. The amount of silver it contains varies from 46·76 to 62·32, and it sometimes contains a little gold. It is found in the Savodinski mines in the Altai mountains, and at Nagyag in Siebenburg.

Figs. 9 and 10.—Silver Glance, Sulphate of Silver.

Crystallises in cubes (Fig. 9), which sometimes take an arborescent arrangement, and are distorted, as in Fig. 10; sometimes also in octahedrons, arborescent, capillary, and as crusty like coatings. The crystals exhibit the crossings of the leaves of the cube, and are sometimes aggregated with red silver ore, or also with native silver, of a lead to iron-grey colour, of slight metallic lustre, and so malleable that they can be easily cut and engraved with a knife, by which peculiarity the ore may be readily recognised. The hardness is = 2·0—2·5, the specific gravity = 6·8 to 7·2. Before the blow-pipe it melts readily, with evolution of sulphurous vapours, and there is left as residue a grain of pure silver. With borax and salt of phosphorus a small amount of copper and iron are generally indicated. The constituents are as follows: simple sulphuret of silver = $\acute{A}g$, with 87·1 of silver and 12·9 of sulphur. In nitric acid it is easily soluble with separation of sulphur, which by boiling is changed by agitation into sulphuric acid.

It is one of the most valuable of silver ores, and occurs in the Erzgebirge of Saxony and Bohemia, frequently also in Schemnitz and Kremnitz in Hungary.

Fig. 11.—Brittle Glance Silver, Melanglance, Prismatic Black Silver.

Crystallises in right rhombic prisms of 115° 39′ and 64° 21′; it occurs, however, in hexagonal prisms, like Fig. 11, in secondary tables, and with truncation of the basal edges, also compact and disseminated. Iron-grey, with metallic lustre, somewhat friable, of 2·0—2·5 hardness, and 6·2—6·3 specific gravity. It is a combination of 6 eq. of simple sulphuret of silver and 1 eq. of sesqui-sulphuret of antimony = $\acute{A}g^6\,\dddot{S}b$, the sulphuret of antimony being sometimes replaced by the sulphuret of arsenic, and a part of the silver by iron or copper. Before the blowpipe it fuses readily, gives off antimonial (or arsenical) vapours; at last there is left a grey metallic grain, which, when heated with soda, yields pure silver. It is soluble in nitric acid. An extremely valuable silver ore, which principally occurs in the primary rocks in Bohemia and Hungary, as well as at the Hartz, and not unfrequently in Peru and Mexico, and is, in all these places, made use of for obtaining silver. It was also at one time found in the Black Forest of Bohemia.

White silver ore may occur in rectangular octahedrons; it is usually, however, finely granular, inclining to compactness, without distinct foliated structure, lead-grey passing into iron-grey; so that, with regard to colour and lustre, it holds a middle place between lead-glance and grey copper or fahlore. Specific gravity 5·4. There are lighter and darker varieties. The principal elements are sulphuret of silver, sulphuret of lead, and sulphuret of antimony; the light variety contains, according to Klaproth, 20·4, the dark 9.25 per cent of silver. A very valuable silver ore, which occurs principally at Freiberg in Saxony and at Przibram in Bohemia.

The *polybasite* (Fig. 12) crystallises in rhombohedrons and hexagonal prisms, sometimes with truncations of the basal edges, as in Fig. 12, it is iron-black and soft, with a hardness of 2·0—2·5. It is a silver-glance containing copper, which occurs at Freiberg, Schemnitz, and in Mexico.

Fig. 13—16. Red or Ruby Silver Ore, Silver-Blende.

The primary form is a rhombohedron, similar to that of calcite, of 108° 18′, which usually occurs with truncation of the vertical and basal edges, as Fig. 15, or in combination with the scalenohedron, as Fig. 16; it is also found in hexagonal prisms, as Fig. 14, or in combination with several rhombohedrons, with a lenticular and drusy arrangement, as Fig. 13, sometimes also in compact or foliated masses. Hardness 2·5—3, specific gravity 5·53—5·85. Lustre metallic to lustrous. Blackish-grey passing into cochineal and carmine-red, with crimson streak; friable. We distinguish between a dark and a light red silver ore; the former is an *antimonial silver blende*, a combination of three equivalents of simple sulphuret of silver and one equivalent of sesqui-sulphuret of antimony ($\dot{Ag}^3 \dddot{S}b$), containing 58·949 of silver, giving on the charcoal an ash of antimony and sulphur, and leaving as residue a grain of silver. It is found in remarkably fine crystals, as Fig. 14, at Freiberg and Joachimsthal, also in the Hartz and in Hungary, as well as in very considerable quantity at Zacatecas in Mexico. The light-red silver ore is an *arsenic-silver-blende*, translucent with a red colour, of adamantine lustre and a light-red streak. The composition is the same as that of the former, except that the sulphuret of antimony is replaced by the sulphuret of arsenic, thus = $\dot{Ag}^3 \dddot{A}s$. On the charcoal it gives strong arsenical vapours, and leaves a grain of silver; in the retort the sulphuret of arsenic is sublimed, and the sulphuret of silver remains behind. It occurs in remarkable quantities at Andreasberg in the Hartz, also in the Erzgebirge and the Schwarzwald, sometimes along with the dark-red ore. Fig. 13 represents a druse from Andreasberg.

There are also arsenic and antimony silver blendes, and still other similar combinations. The *xanthokon*, of 4·14 specific gravity, is one of these changed red silver ores of orange-yellow streak, with 64 per cent. of silver, which is found at the Himmelsfürst mines at Freiberg, and crystallises in rhombohedral tables.

Fire-blende is a foliated, pearly lustrous, orange-yellow, silver-blende, which contains 62·3 of silver, together with antimony and sulphur. It is found as a rarity at the Kurprinz mines at Freiberg, and at Andreasberg.

Miargyrite is oblique rhombic, of adamantine to metallic lustre, of 2·0 hardness, and 5·2—5·4 specific gravity, opaque, and consists of equal proportions of simple sulphuret of silver and sesqui-sulphuret of antimony = $\dot{Ag}\ \dddot{S}b$; the amount of silver contained is 36·40. It is found at Bräunsdorf in Saxony.

Chloride of Silver, Horn-Silver, Kerate,

Crystallises in cubes of indistinct foliated structure, sometimes with truncation of the angles and edges. It is found, however, more frequently disseminated as a crust-like coating, or in compact masses. When fresh it presents a bright adamantine lustre, and is transparent; in the light it becomes pearl-grey, violet, blackish, and opaque. Very soft and malleable, so that it may be forged and cut. Hardness 1·0—1·5, specific gravity 5·5—5·6. It is simple chloride of silver, Ag Cl, composed of 76 of silver and 24 of chlorine. It melts readily before the blow-pipe, gives off chlorine vapours, and leaves as residue a grain of silver. When fused with protoxide of copper, and salt of phosphorus, the bright blue flame of chloride of copper is produced. In nitric acid it is insoluble, and only partially soluble in caustic ammonia. Is found in remarkably fine crystals at the Markus Reling mines at Schneeberg in Saxony, and at St. Jago in Chili. It was at one time found in compact masses at Schneeberg, in the Royal Collection of Minerals at Dresden, there is a fragment of about 7 pounds weight, which is said to have been found below the church of Schneeberg, exactly under where the high altar now stands.

The so-called *gosling-green silver* is a chloride of silver mingled with clay and earthy cobalt, which occurs at Schemnitz in Hungary, and at Andreasberg in the Hartz mountains.

Bromide of silver crystallises in cubes, and is of a pearl-grey colour, passing into siskin-green, unchanged by light; it consists of simple bromide of silver, Ag Br. Is found in the district of Plateros in Mexico; and *chlorobromide of silver* occurs at Copiapo in Chili. *Iodide of silver* is found in Mexico and Chili, in thin translucent leaves, of adamantine to resinous lustre, pearl-grey, malleable and flexible, of 1·5 hardness, and is simple iodide of silver, containing 77·4 of silver, and 22·6 of iodine. It colours flame purple-red, and when heated with a little hydrochloric acid in a test-tube, gives off vapours of iodine.

Seleniuret of silver, which crystallises in hexagonal prisms. Is found at Tasco in Mexico, as a double seleniuret of silver; it has a lead-grey colour, with slight metallic lustre, and is malleable. It is dense and iron-grey, passing into reddish, at Tilkerode in the Hartz; and is here a simple seleniuret of silver, rendered impure by seleniuret of lead, and contains 65·56 per cent. of silver.

II. COMMON METALS.

PLATE XV.

Fig. 1—5.—Quicksilver, Mercury.

Mercury is a simple metal, which is liquid at ordinary temperatures. It is scantily distributed in nature, and is always found only in the igneous and older stratified rocks, either in veins or beds. It occurs native, in combination with silver, as an amalgam, mineralised by sulphur as cinnabar, as well as combined with chlorine and iodine, and also as an element of some fossil ores. The principal ore, however, is cinnabar, from which it can also be extracted with facility by simple burning; from its being liquid, and having only a slight affinity for oxygen, it approaches in this respect the noble metals.

Fig. 1.—Native Amalgam.

This name is applied to the combinations of silver and mercury which occur in nature. The primary form is the rhombic dodecahedron, and crystals occur similar to those of the garnet (Plate II. Fig. 8 and 9), also truncations of the edges and cubic angles, as in Plate XV. Fig. 1, and the crystals are sometimes of the same size as the figures. It, moreover, occurs dense, globular, lamelliform, and disseminated, the upper surface is also often as it were corroded; the fracture is partially conchoidal, partially foliated. It is pure silver-white, with a high degree of metallic lustre, and has a greasy feel, opaque, of 3·0—3·5 hardness, and 13·7—14·1 specific gravity. Before the blow-pipe, or when heated in the retort, the mercury evaporates, and a grain of silver is left. According to Klaproth, it contains 64 of mercury and 36 of silver, and is therefore a double hydrarguret of silver = Ag Hg^2. It is found especially at Moschel, and at the Stahlberg in the Zweibrucken district, also at Almaden in Spain, and at Szlana in Hungary.

Arquerite crystallises in octahedrons, and resembles the foregoing; it is silver-white, malleable, of 1·5—2·0 hardness, and 10·8 specific gravity. It contains 86·5 of silver, and 13·5 of mercury = Ag^6 Hg, and is found with native silver in the silver-mines of Arqueros in Chili. The appearance is that of native silver.

Fig. 2.—Native Mercury.

Liquid, or disseminated in small drops, silver-white, of metallic lustre, opaque. It is solid and ductile at a temperature of 39° Fahr., and may then be obtained in octahedral crystals. In heat it volatilizes perfectly, and leaves a white tarnish on a plate of copper held over it; at an ordinary temperature it also volatilizes by degrees. It is besides readily covered with a grey coating, by which it loses its friability, and makes marks on paper, especially if it contains lead, bismuth, or iron. It is readily soluble in nitric acid, the dilute solution is precipitated by a plate of metallic copper.

Mercury exercises a remarkably solvent effect on some metals, as, for example, on gold and silver, as well as on tin, zinc, copper, and other metals; and for this reason, it is often used for separating the two first by the process of amalgamation, for which it is the more suitable that it can again be abstracted by distillation. It is thus also used for gilding other metals by heat, especially copper, bronze, and iron, for the backs of mirrors, for barometers and thermometers, and for collecting such gases as are soluble in water in the mercurial trough; also for different chemical apparatus, and in medicine. All the compounds of mercury are poisonous, some of them, the chloride, for instance, in a very high degree. Mercury is found always along with cinnabar, as in Fig. 2, which is from Mörsfield in Rhenish Bavaria; it also occurs at Idria in Carniola, Horzewitz in Bohemia, Almaden in Spain, in Peru, China, etc. In general in small quantity; nevertheless, at one time, in blasting a rock containing cinnabar at Moschel, a mass of 13 lbs. was collected. The native mercury is in general very pure, or it contains only traces of silver, bismuth, and iron; that which occurs in commerce generally contains some lead.

Fig. 2—5.—Cinnabar, Sulphuret of Mercury, Mercury-blende.

The primary form is a rhombohedron of 71° 48′, which, however, for the most part, occurs in combination with two other obtuse rhombohedrons and truncation of the vertical angles, as in Fig. 4, or in secondary rhombohedral tables, as in Fig. 5, crystalline-granular or foliated masses, like Fig. 3, or quite dense varieties, mixed with oxide of iron, and sometimes containing carbon or bitumen; the so-called steel, liver, and coral ores are, however, more frequent. It is also found fibrous, arborescently disseminated, earthy, and of a deep red colour, as in Fig. 2. In the crystallised varieties the colour is cherry-coloured, passing into crimson; in the spathic and earthy varieties, dark or cochineal red; the streak is scarlet. The crystals are semi-transparent, of adamantine lustre. Liver-ore and steel-ore appear frequently, of a brown red, passing into iron-grey, and the streak gives a dirty red mark. Pure cinnabar has an uneven fracture, is only slightly friable, of 2·5 hardness, and 8·0—8·1 specific gravity. On the matrass the sulphur burns, and the mercury volatilizes, when heated in the retort a dark cherry-red sublimate is formed of crystalline cinnabar; mixed with burnt lime or steel filings, globules of quicksilver are obtained by heating in a test tube. The powder is soluble by agitation with nitro-hydrochloric acid. The composition is simple sulphuret of mercury, Ag S, consisting of 86·29 of mercury and 13·71 of sulphur. The principal localities in Europe are, Obermoschel, Potzberg, Landsberg, and Stahlberg in the district of Zweibrucken, Idria in Carniola, Horzewitz in Bohemia, Szlana in Hungary, and Almaden in Spain; California, Peru, Mexico, Brazil, China and Japan also furnish considerable quantities.

Cinnabar sometimes occurs in commerce by itself, finely ground, and is used as an artist's colour (vermilion); it is principally employed, however, for obtaining mercury. Idria and Almaden yield most of the mercury for Europe.

Chloride of mercury, horn quicksilver, crystallises in small quadratic prisms. White, passing into grey and yellow, of adamantine lustre, translucent, of 1·5 hardness, and 6·5 specific gravity. It is a sub-chloride of mercury, Hg_2 Cl, or a proto-chloride Hg Cl, composed of 84·9 of mercury and 15·1 of chlorine. It volatilizes perfectly in the retort; and on the matrass with oxide of copper and salt of phosphorus gives a blue flame.

Iodide of mercury, of a deep-red colour, is said to occur in Mexico; *seleniuret of mercury*, of the lead grey colour, and appearance of grey copper, consisting of 25·5 selurium and 74·5 mercury (Hg^6 Se^5) has been found at Zorge in the Hartz, and was formerly taken for native selenium. *Mercury-lead-seleniuret*, of similar appearance, and, like the last mentioned, giving off vapours of selenium and mercury, but at the same time leaving a yellow tarnish as residue, is found with seleniuret of lead at Tilkerode in the Hartz mountains.

Copper.

The only red metal occurring in nature, and which, by its malleability and toughness, as well as by its durability in air and water, has recommended itself, from the earliest times, for all kinds of purposes in the arts. It occurs

native, variously mineralized with sulphur, in simple and double combinations with other metals, especially with iron, antimony, arsenic, and lead; also oxidized, and in many compounds with acids, especially with carbonic, phosphoric, and arsenic acids, sometimes in great abundance. These ores frequently exhibit very fine shades of red, blue, and green, and are thus the ornaments of mineral collections. All copper ores by themselves colour the flame of the blow-pipe green, and if they are first moistened with hydrochloric acid, a dark blue; and by this test the faintest traces of copper may be recognised. All of them, when heated with borax, give a bluish-green pearl, which, in the inner flame, or on the addition of a grain of tin, takes on a red colour of separated oxide or of metallic copper. Most of them, on being properly heated with soda, yield a grain of copper on the charcoal, which may be distinguished by its ductility and red colour. All the compounds are poisonous; the solutions in acids are green or blue, and are precipitated by smooth iron or zinc plates.

Fig. 6—8.—Native Copper.

Crystallises in the various forms of the regular system, cubes, octahedrons, dodecahedrons, etc. The crystals are, however, for the most part distorted, so that prismatic and wedge-shaped forms of all kinds arise, as seen in the specimen, Fig. 7, from Katherinenburg; sometimes icosahedrons are found in combination with the cube, as Fig. 6, which is from Lake Superior in the United States, where crystals of an inch in size frequently occur. Arborescent and shrub-like forms, like Fig. 8, which is from Cornwall; dense, irregular masses, of from one to two tons, have been found at the Urals, in New Caledonia, at Lake Superior, and more lately in Van Diemen's Land. It is often perfectly smooth, as if polished; in other cases, tarnished brown-red, as in Fig. 8. The streak is copper red, highly lustrous; the fracture hackly, the hardness 2·5—3·0, and the specific gravity 8·4—8·9. The composition is generally pure copper (Cu), often with traces of silver, gold, and iron. That from Lake Superior is frequently mingled with native silver, and is found in a serpentine amygdaloid. It occurs in many of the mines of Cornwall and Devon, in the trap-rocks near Stirling, the new red sandstone near the railway tunnel at Mauchline in Ayrshire, etc. The largest blocks are found in this country in the serpentine near the Lizard, where they have been found of half a ton weight. Most of the copper of commerce is obtained, however, from the different copper ores, especially from copper pyrites, cuprite, azurite, and malachite, and a good deal also from the cupriferous slate, as, for example, in the Mannsfeld.

Copper was, under the name of Cyprian ore, used by the ancients, partly by itself, and partly in combination with tin in a bronze-like alloy, for weapons and household vessels of different kinds, and is yet widely applied to the manufacture of kettles and distilling apparatus, to the covering of roofs, sheathing of vessels, to plates and cylinders for smoothing clothes, paper, etc., electrotyping and different works in the arts, as wire for telegraphs, musical instruments, etc.—all purposes for which its tenacity, elasticity, and durability in the atmosphere and under water render it peculiarly suitable. Yellow metallic mixtures of great variety are produced by alloying it with tin and zinc, and are known as *bronze*, *gun* and *bell metal*, *pinchbeck*, *Dutch gold*, *brass*, etc. With nickel and zinc it forms white alloys, which are known as *German silver*, *tutenague*, etc. and, to a certain extent, take the place of silver. With arsenic it forms the alloy known on the Continent as *white copper*. From the waste of copper different colouring stuffs, used in chemical preparations, are made, such as verdigris, Scheele's green, blue vitriol, etc. Many preparations of copper are also used in medicine, in painting, and in printing; in chemistry, as re-agents, etc.

Sulphurets and Sulphates of Copper.

The copper ores containing sulphur are very frequent, and often contain, in addition to the sulphuret of copper, sulphurets of iron, antimony, arsenic, and lead, sometimes also silver and gold, in which case they are principally applied to the production of the noble metals. The separation of copper from the common metals above mentioned is effected by various, often very complicated processes, especially by repeated heating, concentration, and the use of black oxide of copper, which is obtained either by cupellation or the amalgamation process; sometimes also in the moist way.

Figs. 9 and 10.—Copper-glance, Vitreous Copper, Chalcosine.

Crystallises in right rhombic prisms, sometimes with truncation of the acute lateral edges, as Fig. 10, a small group from Cornwall; dense masses, of a leaden to a steel-grey colour, are more frequent, sometimes exhibiting an indigo-blue tarnish, and more or less metallic lustre. The streak is bluish or blackish-grey, tolerably friable, of even fracture, 2·5—3·0 hardness, and 5·5—5·8 specific gravity, opaque. It is a sub-sulphuret of copper, Cu_2S, composed of 20·27 parts of sulphur and 79·73 of copper. Before the blow-pipe it fuses, the sulphur is consumed, and a grain of copper is left on the charcoal. It is one of the most valuable copper ores, which occurs especially in Cornwall, the Bannat, in Connecticut, in small quantities also at Rudelstadt in Silesia, and as the petrifying medium of small pieces of the fruit of a cypress (Cupressites *Ullmanni*), under the name of Frankenberg corn-ears, in Hessia, also at Nassau and the Erzgebirge.

The *Copper-indigo* or *Covelline* is an indigo-blue, almost triturable, simple sulphuret of copper; dull, opaque, of 1·5—2·0 hardness, which principally occurs with copper pyrites at the Schwarzwald, also in Salzburg and Thuringia. Fig. 11 represents such a piece from Herrensegen in the Schapbachthal, where the indigo-copper partially covers the copper pyrites. In Salzburg it is said to have been found in hexagonal prisms.

Figs. 12 and 13.—Erubescite, Variegated Copper Ore.

Crystallises in regular octahedrons, which are frequently irregularly aggregated on one another, as in Fig. 13, a specimen from Cornwall. More frequently it has been

found in dense masses, as for example at Schneeberg (Fig. 12), of uneven fracture, with violet, blue and green tarnish, passing into copper-red, and pinchbeck-brown, with greyish black streak, opaque, and of feeble metallic lustre; slightly friable, of 3·0 hardness, and 5·0 specific gravity. It is a combination of 4 eq. sub-sulphuret of copper, and 1 eq. of simple sulphuret of iron ($\dot{F}e\ \dot{C}u^4$); the dense ores yield from 56—61 per cent. of copper. Before the blow-pipe it behaves like copper-glance, by which the oxide of iron is separated. It is found in Nassau, Thuringia, Saxony, and Silesia, in Sweden and Norway, and in Cornwall, and is everywhere smelted with the other copper ores.

Figs. 11, 14, 15, 16.—Copper Pyrites or Chalcopyrite.

The primary form is a square octahedron, like Fig. 15, in which, however, the half of the faces are frequently increased at the expense of the others, so that the tetrahedral form predominates, as in Fig. 16, or several such crystals are united as twins, as in Fig. 14. Most frequently dense masses occur of a brass-yellow colour, and uneven fracture, like Fig. 11; and these are usually mixed with dense sulphur pyrites, so that the ores often give a very small share of copper. The colour is always deeper yellow than in iron pyrites, and sometimes iridescent, with play of colour passing into greenish and bluish, or gold-yellow; the streak is greenish-yellow, the metallic lustre striking, the hardness = 3·5—4·0, consequently it cannot strike fire with steel, and by this peculiarity it may be readily distinguished from sulphur pyrites.

Copper pyrites consists of equal proportions of simple sulphuret of copper and sesqui-sulphuret of iron $\dot{C}u\ \dddot{F}e$, and in a pure condition contains 34·47 of copper, 30·4 of iron, and 35·05 of sulphur, to which there is occasionally added a small amount of silver or gold. When heated on the charcoal it leaves a brown-red residue, from which by itself only by continuing the blowing, but more readily on the addition of some soda, and, more easily still, with cyanide of potassium, a granule of copper is obtained. It is one of the most valuable of copper ores, which frequently occurs in large layers and blocks in the primary, and older stratified formations, as for example at Röraas in Norway, at the Rammelsberg near Goslar, at Fahlun in Sweden; it also occurs frequently in the Herrensegen and St. Michael mines in the Schwarzwald, in Nassau, Styria, Tyrol, Silesia, England, and France. The finest crystals, as in Figs. 14 and 16, are found in Cornwall, and at the Erzgebirge in Freiberg. In many places quite poor ores, with so low as 6 per cent. of copper, are smelted, when mixed with richer varieties; the sulphurous vapours which are given off are also sometimes employed in the preparation of sulphuric acid.

Fig. 17—20.—Grey Copper Ore, Tetrahedrite, Fahlore.

Crystallises in regular tetrahedrons, which are sometimes arranged in a druse, like Fig. 17, and presents an indistinct foliated structure, corresponding to the primary faces; truncation of the angles, as in Fig. 18, or double truncation of the edges, the tetrahedron in combination with the pyramidal tetrahedron, as Fig. 19; also simple truncation of the edges (cube), besides triple replacement of the angles (second pyramidal tetrahedron), as Fig. 20, and also thick masses, are of frequent occurrence. Steel-grey, strongly lustrous, occasionally with a variegated tarnish, streak black; friable; fracture conchoidal, uneven, hardness 3·0—4·1, specific gravity 4·79—5·1.

The grey copper ores form remarkable double combinations of sulphuret of copper, sulphuret of antimony, or sulphuret of arsenic, sometimes with sulphuret of silver, sometimes with sulphuret of zinc, or with sulphuret of iron and sulphuret of mercury; and in the first rank we distinguish *antimony*, and *arsenic grey copper*, as well as grey copper, with and without silver, with zinc, mercury, etc. The above-mentioned metallic sulphurets sometimes occur in combination with one another, and there are varieties containing bismuth and lead as well. The arsenic tetrahedrite is usually somewhat lighter in colour, and contains 38·63—42·50 of copper, with a proportion of silver of 0·50—2·37. The antimony tetrahedrite, also known as schwarzerz, and dark fahlore, contains 14·81—25·50 of copper, and 13·25—31·29 of silver. The mercury fahlores contain 34·57—35·76 of copper, and 15·57—17·27 of mercury. Before the blow-pipe all of them give sulphurous vapours, and more or less antimony or arsenical smoke; a grain of copper containing silver remains as a residue on the charcoal, from which, by means of lead, and repeated refining by animal charcoal, the silver may at last be obtained pure. This is more easily effected in the moist way, in which the grain of metal is dissolved in pure nitric acid, and the dilute solution precipitated by copper. The light fahlore is found at Freiberg, Klausthal, at Kapnik, and Schemnitz in Hungary, at Schwatz in the Tyrol; the dark variety also occurs at Freiberg, at St. Wenzel in the Schwarzwald, and in Hungary. The fahlores are usually smelted for copper and silver, that containing quicksilver from Schwatz in the Tyrol, Poratsch in Upper Hungary, and Moschellande, also yielding quicksilver.

PLATE XVI.

Fig. 1—3.—Cuprite, Red Oxide of Copper.

Crystallises in regular octahedrons, which sometimes occur in remarkable groups, as, for example, in Siberia (Fig. 1); truncations of the edges, as in Fig. 2, and rhombohedrons, as in Fig. 3, are also found; these are, for the most part, covered by a coating of earthy malachite, and occur principally at Chessy, near Lyons. Very fine cubes are found in Cuba; dark red needles and capillary crystals, with a fine velvety silky lustre, which are known as *chalcotrichite*, at the Virneberg at Rheinbreitenbach; dense and foliated masses also occur principally in Cornwall and Siberia.

The colour varies from cochineal-red and lead-grey to crimson-red; the streak is light to darkish-red, the lustre inclining sometimes to adamantine, sometimes to metallic.

The smaller crystals are transparent, larger ones are scarcely translucent. The fracture is uneven to conchoidal, the hardness = 3·5—4·0, the specific gravity = 5·7—6·0.

Cuprite is, in its pure state, protoxide of copper (Ċu), composed of 88·78 of copper and 11·22 of oxygen, and is therefore a very valuable copper ore. It is reducible on the charcoal, and colours the flame green. In acids it is readily soluble.

The *ziegelerz*, or *tile-ore*, is a brown-red cuprite, containing oxide of iron, frequently mixed with copper pyrites, which occurs in dense masses, especially with malachite, as in Fig. 11, in the Scharzwald, at the Herrensegen and St. Michael mines, in Nassau and Thuringia, in Chili, and at several Cornish mines, and is also smelted to copper.

Fig. 4—7.—Azurite, Chessylite, Blue Carbonate of Copper, Blue Copper.

Crystallises in oblique rhombic prisms of 98° 15′, which often occur in elegant groups, sometimes covered with small needles of malachite, as, for example, at Chessy (Fig. 4). Low tables are also found with truncation of the obtuse lateral edges and of the obtuse angles (Fig. 5), or with truncation of the obtuse basal edges and of the acute angles (Fig. 6), and radiating foliated aggregations (Fig. 7) are also found. The last-mentioned specimen is from the veins of the variegated sandstone of Neubulach in the Schwarzwald (Black Forest). It is, moreover, found exceptionally, earthy and shrub-like, of a dark blue, as in Hungary and at the Urals. The colour is generally of a deep azure blue, often very sparkling; sometimes it is lighter. The crystals are of vitreous lustre, translucent, sometimes dull, of conchoidal or even fracture, brittle, of from 3·5—4·0 hardness, and 3·83—3·90 specific gravity. The composition is 2 eq. of carbonate of copper, and 1 eq. of hydrous oxide of copper (2 Ċu C̈ + Ċu Ḣ). Before the blow-pipe it melts, and yields a grain of copper on the charcoal. In the closed tube it gives out water, and remains as black oxide of copper.

The distribution of this ore is not wide; the finest crystals are found at Chessy; and in Hungary, where it occurs pure, when reduced to a fine powder, it is sold as a blue paint of a bright tint; but is of little value, owing to its liability to become green; it is sometimes also smelted with other copper ores.

Fig. 8—12.—Malachite, Green Carbonate of Copper.

Crystallises likewise in oblique rhombic prisms, of 103° 42′, which sometimes occur in small bundles of crystals, as in Fig. 8, and are generally acicular; truncations of the obtuse lateral edges and twin composition, as in Fig. 9, are also found; radiated fibrous masses of the finest emerald-green as, for instance, in Siberia (Fig. 10), or dark-green bunches (Fig. 11), as at the Herrensegen in the Schwarzwald, are more frequent. These are all encrusted on a compact red ore. The compact malachite occurs tuberose, botryoidal, and reniform, of a more decided blue-green colour, in Siberia (Fig. 12). Earthy malachite is found with the other varieties, and also in Hungary, and in the Schwarzwald.

The colour varies from dark, or blackish-green, and emerald-green to blue and whitish-green. The lustre is between vitreous and silky; the fracture is uneven; the hardness 3·5—4·0, the specific gravity 3·67—40. The crystals or fine needles only are transparent. The composition is subcarbonate of copper and ½ eq. water; the chemical relations are the same as those of azurite. It is also in the same way used for copper. The larger, pure pieces of the fibrous and compact malachite of Siberia are, moreover, used for making small objects of ornament and art. The mines of Count Demidoff at Nischni-Tagilsk yield extraordinarily fine specimens, which sometimes measure several cubic feet, so that whole tops of tables and vases have been made from them. Australia now furnishes us with specimens of malachite which are scarcely inferior in appearance to the finest Siberian varieties.

Fig. 13—15.—Phosphate of Copper.

There are two phosphates of copper, one prismatic, the other octahedral; the former (Fig. 13) is known as *phospho-calcite*, *pseudo-malachite*, or *Lunnite*, the latter as *libethenite* (Figs. 14 and 15).

Phospho-calcite crystallises in oblique rhombic prisms; it occurs, however, more frequently in acicular and drusiform crystals; it has the appearance of malachite. It is a phosphate of copper with 1 eq. of water, emerald green, translucent, of 4·5—5·0 hardness, and 4·2 specific gravity, and is soluble in acids without effervescence. It is found at Rheinbreitenbach and in Peru, and compact with the appearance of compact malachite at Libethen in Hungary, the so-called *prasim*. Only one specimen has yet been found in Britain, "it is from Cornwall, and is now in Mr. Greg's collection." (Greg and Lettsom, p. 323.) Libethenite crystallises in rectangular octahedrons (Fig. 14), and in combination with the rhombic prism and truncation with two vertical edges (Fig. 15), of dark, olive-green colour, generally imbedded in quartz at Libethen in Hungary. The crystals are of vitreous lustre, translucent, brittle, of 4·0 hardness and 3·6—3·8 specific gravity, and dissolves without effervescence in nitric acid. The composition is phosphate of copper, with 2 eq. of water. Occurs also at Rheinbreitenbach and in Cornwall.

Figs. 16 and 17.—Emerald Copper, Dioptase, Achirite.

One of the finest copper ores, with the colour and appearance of the finest emeralds. The primary form is a rhombic hexahedron, of which however the basal edges are truncated, as in Fig. 17. The primary form also occurs with extension of two pairs of planes, so that the crystals are oblique rhombic prisms, like Fig. 16; they are generally imbedded in quartz; brittle, of vitreous lustre, transparent, hardness 5·0, specific gravity 3·27, composition two-thirds of silicate of copper, with 3 eq. of water. Soluble in nitric acid, separating a jelly of silica, and before the blow-pipe it gives the reactions of oxide of copper

and silica. Until now it has only been found in the Kirghese Steppes, west from Altai in Siberia, and one of its names, *achirite*, is derived from Achir Mamed, a Buchárian merchant, who first brought it to Europe.

Fig. 18—22.—Arseniates of Copper.

The compounds of arsenic with oxide of copper are exceedingly numerous, a complete series of them being known, and many of them also contain arseniate of iron. They occur only sparingly, however, and serve rather as an ornament of mineralogical collections than as an object of any great value as an ore.

Liroconite, of a verdigris-green to a sky-blue colour, crystallising in right rhombic prisms, sometimes in secondary tables (Fig. 19) is found at Huels, Gorland, and Unity, in Gwennap, in Cornwall. Fig. 20 represents an isolated crystal.

Euchroite, emerald-green, usually aggregated in rhombic octahedrons, as in Fig. 18, is found in quartzose mica slate at Libethen, in Hungary.

Olivenite, Fig. 21, dark olive-green, in Cornwall, Devonshire, and Cumberland. The *wood arseniate*, with soft, velvet surface, and greenish-grey appearance, is a variety of olivenite, and is also found in Cornwall.

Copper Mica, or *Chalcophyllite*, in blue-green, pearly-lustrous foliated masses, or rhombohedral tables, like Fig. 22, from the same place.

Fig. 23.—Blue Vitriol, Sulphate of Copper, Cyanosite.

Crystallises in oblique rhomboidal prisms, sometimes with truncation of the obtuse lateral edges, like Fig 23, and of the acute basal edges and solid angles; sky-blue, of vitreous lustre, translucent, brittle, hardness 2·5, specific gravity 2·2—2·3. Crystals are very rare, more frequently it occurs in crystalline encrustations, or stalactitic, generally as a product of decomposition of copper pyrites in old mines, as, for example, in Salzburg and Rammelsberg, in Cornwall, Anglesea, and Wicklow. The copper is extracted from it by laying iron bars in the pits, and on the iron being dissolved, it is replaced by a deposit of copper. At Wicklow, 500 tons of iron having been thus introduced, the iron was dissolved in a year, and every ton of iron yielded from a ton and a-half to two tons of reddish mud, which was principally oxide of copper, each ton yielding about 16 cwt. of pure metallic copper. Blue vitriol is manufactured mostly from old copper and the residue of smelting. The composition is simple sulphate of copper, with 5 eq. of water = $\dot{C}u\,\ddot{S} + 5\,\dot{H}$. Blue vitriol is used for many purposes, in colouring calico and other stuff printing, in galvano-plastic operations, and in medicine.

Brochantite is basic sulphate of copper, with 3 eq. of water, and crystallises in right rhombic prisms, which are emerald-green, of vitreous lustre, and transparent. It occurs at Retzbanya and Libethen, in Hungary, at Roughtengill in Cumberland, and at Katherinenberg in Siberia.

Atacamite, or *chloride of copper*, crystallises in right rhombic prisms and needles; more frequently it is found with cuprite in crystalline-granular aggregations, or foliated as in Chili and Peru, or disseminated, as in the lavas of Vesuvius and Etna. It is chloride of copper with 3 eq. of hydrous oxide of copper, of 2·5 hardness, and 4·43 specific gravity, emerald-green passing into olive-green, slightly to vitreo-lustrous, translucent, and colours the flame of the blow-pipe a magnificent blue, and at last green. When reduced to powder it is sold in Chili under the name of *arsenillo*, as a green sand for sprinkling over newly-written letters.

PLATE XVII.

Fig. 1—4.—Nickel Ores.

Nickel is sparingly distributed in nature, and is principally limited to veins and lodes of the older rocks. It is not found native, but usually in combination with sulphur, arsenic, cobalt, or oxygen. Most of the ores have a metallic appearance, and when heated yield a yellowish-green oxide, which, with borax, gives a brownish-red glass, and which, on the addition of a salt of potash, becomes blue; when held in the reducing flame, however, metallic nickel is separated in silver-white spangles, which follow the magnet on being washed out, nickel showing the highest degree of magnetism with the exception of iron. With cyanide of potassium the assay yields a loose, infusible, spongy grain of metallic nickel, which is likewise attracted by the magnet. If there is cobalt in the ore, the assay gives a blue pearl with borax. Most of the metallic nickel is obtained from the various arsenic compounds, and also from the residue which, under the name of *speiss*, is obtained from the preparation of smalt from cobalt ore. It is used in the manufacture of german silver or argenant, in which it is alloyed with copper and zinc.

Fig. 1.—Millerite, Sulphuret of Nickel, Capillary Pyrites.

Is found in capillary crystals and small hexagonal prisms arranged in bundles, like Fig. 1, brass-yellow to steel-grey, sometimes playing in a variety of colours; lustre metallic, opaque, hardness 3·0—3·5, specific gravity 5·27—5·65. It is simple sulphuret of nickel, $\dot{N}i$, generally, however, containing copper and iron; on the charcoal it gives sulphurous vapours, and deposits metallic copper on being heated in the inner flame; it is found in hornstone at Johanngeorgenstadt in Saxony, and at Joachimsthal in Bohemia, also at Duttweiller near Saarbruck, in Cornwall, and at Ebbw Vale near Merthyr-Tydvale, but always in small quantity.

Fig. 2.—Copper Nickel, Red Arseniet of Nickel, Arsenical Nickel.

Is said to crystallise in hexagonal prisms; is found, however, generally in a crystalline state, compact, globular,

or columnar. It is of a copper-red colour, passing into grey and brown, sometimes with a variegated tarnish, the streak is copper-red; of metallic lustre, brittle, hardness = 5·0—5·5, specific gravity 7·6. It is simple arseniet of nickel = Ni As, but the arsenic is sometimes replaced by antimony, and it contains 44·20 of nickel. Before the blow-pipe it melts with evolution of arsenical fumes. It is found mixed with white nickel, usually also with some smaltine, as in Fig. 2, at Riechelsdorf in Hesse, Schneeberg in Saxony, Joachimstal in Bohemia, Schladming in Styria, at the Harz, also in Wales, Hungary, France, England, and Scotland, and is employed for obtaining metallic nickel. The piece figured shows this mineral on the left, which may be recognised by its red colour, with white nickel on the right. The upper surface is studded with small cubes of smaltine, and has an iridescent tarnish. The oxide of nickel obtained from this and other nickel ores is used in porcelain and glass painting for the production of different shades of green.

Fig. 3.—Chloanthite, White Arseniet of Nickel, White Nickel.

Crystallises in cubes, as Fig. 3, variously aggregated, sometimes with truncation of the angles and edges, colour tin-white, passing into grey and iron-black, of uncertain cleavage, slight metallic lustre and usually tarnished with a pale green, by which it is readily distinguished from the other nickel ores. In the retort it gives a metallic deposit of arsenic, and on the charcoal a strong arsenical vapour. The blow-pipe test gives a blue pearl with borax, which, according to the amount of cobalt it contains, is more or less easily reduced to metallic nickel. The specimen figured is from Schneeberg, where it is only found in crystals; it also occurs at Kammsdorf in Thuringia, and Sangerhause in the Erzgebirge, at Riechelsdorf in Hesse, as in Fig. 2, and at Tanne in the Hartz. It is a double arseniet of nickel = Ni As_2, and generally contains some antimony or cobalt, consisting of 28·22 of nickel, and 71·78 of arsenic; it is principally manufactured into metallic nickel.

Antimonial nickel, crystallizing in hexagonal prisms, copper-red, of metallic lustre, consisting of simple antimoniet of nickel, and similar to the red arseniet of nickel, and containing 31·20 of nickel and 56·79 of antimony, is found at Andreasberg in the Hartz.

Nickeliferous grey antimony or *ullmanite*, crystallizing in cubes, of distinctly foliated structure, lead to iron-grey, of metallic lustre, brittle, of 4·5 hardness, and 6·2—6·45 specific gravity, is a double sulphuret of nickel, with simple antimoniet of nickel, and is found at Gosenbach and Willensdorf at the Westerwald.

Fig. 4.—Nickel Ochre, and Oxyhydrate of Nickel, Annabergite.

Nickel ochre appears as an apple-green stem-like crust, or in greenish white acicular crystals, as on the left of the specimen figured, and consists of basic arseniate of nickel. The *carbonate of nickel*, or *emerald nickel*, is stalactitic and of an emerald green colour, as the fine fibres on the left show; it is carbonate of nickel, with 6 eq. of water, encrusted on chromic iron, from Bashill, near Baltimore, in the United States of America.

Fig. 5—13.—Cobalt Ores.

Cobalt occurs very much in the same situations as nickel, and their ores are frequently found together. The metal cobalt is also white, and is attracted by the magnet to a small extent, but not so much so as nickel. The ores, on being roasted, leave a black oxide, and give off very strong arsenical vapours; with borax, before the blow-pipe, they give a fine azure-blue glass, which is not changed in the reducing flame. Most of the ores of cobalt present metallic lustre, and a tin-white colour passing into steel-grey. The metal has not been applied to any purpose, and the pure oxide is thus the more valued. It is obtained from the ores, and used for a blue colouring matter in enamel, for the preparation of smalt and other blue pigments.

Fig. 5.—Cobalt Pyrites, Sulphuret of Cobalt.

Crystallises in regular octahedrons, like Fig. 5, which are generally aggregated in druses, and sometimes present small planes of cubes at the corners. It is of a tin-white colour, and strong metallic lustre, which is unaffected by the atmosphere. The streak is grey, the fracture uneven, the hardness 5·5, and the specific gravity 6·2—6·5. The constitution is in general sesqui-sulphuret of cobalt = $\dddot{C}o$, to which is usually added an appreciable amount of sulphuret of nickel. It is found at Müsen in Nassau, and at Riddarhyttan in Sweden.

Fig. 6—9.—Cobaltine.

Crystallises in cubes, octahedrons, pentagonal dodecahedrons, etc., and may be split in the direction of the planes of the cube; the pentagonal dodecahedrons usually predominate, however, as in Fig. 6, where both are combined; or in Fig. 7, where the cube is quite lost, and the octahedral planes predominate; or in Fig. 8, where the planes of the octahedrons and pentagonal dodecahedrons occur in equal proportions, the latter as isosceles triangles, so that the common icosahedron or twenty-faced solid arises. All these crystals come from Tunaberg in Sweden, and Modum in Norway. In Fig. 9, the cube P and the octahedron O are united to the first and second pentagonal dodecahedrons b^1 and b^2. The mineral is also found compact, but never in such large quantities as the grey cobalt or smaltine; as, for instance, at Mariakirch in the Elsass, at Querbach in Silesia, and formerly at Wittich in the Schwarzwald. The colour is tin-white, sometimes passing into reddish, the streak is greyish-white, the metallic lustre is brilliant, the fracture uneven, the hardness = 5·0—5·5, and the specific gravity 5·9—6·2. It is very friable,

and consists essentially of equal proportions of bi-sulphuret of cobalt and bi-arseniuret of cobalt = Co S_2 + Co As_2; bi-sulphuret of iron also frequently enters into the mixture. It gives on the charcoal strong arsenical and sulphureous vapours. A piece held in the reducing flame exhibits magnetic properties if it contains iron, and the borax pearl, saturated with it, appears yellow when heated, but becomes dark-blue when cold. It is one of the most valuable ores, containing, on an average, 33 per cent. of cobalt.

FIGS. 10 AND 11.—SMALTINE, GREY COBALT.

Crystallises in cubes as seen in a few crystals to the right of Fig. 11; more frequently those at the corners are truncated, as in Figs. 10 and 11, so that the octahedron is more or less distinct; rhombic dodecahedrons also occur. The crystals may be split principally in the directions of the planes of the cube, sometimes also in that of the planes of the octahedron. Compact masses of a tin-white to a steel-grey colour are very frequent; they lose their metallic lustre readily in the air, however, and become tarnished with a reddish grey. When fresh, the mineral always presents a strong metallic lustre, and a tin-white colour, more or less inclined to a yellowish or iron-grey; the planes of the crystals are seldom perfectly even, and do not present the brilliant lustre of the ores already mentioned. The fracture is uneven, the hardness = 5·5, the specific gravity = 6·2—6·4; friable. It consists of bi-arseniuret of cobalt Co As_2, containing 20·31 of cobalt, frequently rendered impure by a distinct trace of arseniuret of iron, and sometimes of sulphuret of copper.

The *Iron-smaltine* of Schneeberg contains only 9·44 of cobalt and 18·48 of iron.

Before the blow-pipe smaltine gives a strong arsenical smoke, and if it contains sulphur, along with soda it gives a slag, which on a wet silver coin leaves a black mark; in the retort, when heated, it gives a sublimate of metallic arsenic.

It is the commonest ore of cobalt, and occasionally also occurs in very compact masses, as for example at Schneeberg, Saalfeld, in Nassau and Hesse, Schladming in Styria, Wittich and Wolfach in the Schwarzwald, etc. It occurs along with native bismuth, under the name of *cobalt bismuth ore*, at Schneeberg, and with nickel at Riechelsdorf in Hesse.

Earthy cobalt, or *black cobalt*, is of a bluish-black colour, dim, earthy, sometimes botryoidal, or as pseudomorphs of calcite (the *kakochlor* of Breithaupt), and appears to be a product of decomposition of smaltine and other cobalt ores, and generally contains oxide of manganese and water. The cobalt is sometimes contained in it as the oxide or hydrous oxide, and sometimes as the sulphuret and arseniuret of cobalt. There are also varieties which contain the oxides of copper and iron; most of them are, however, rich in the oxide of manganese, which may be easily recognised by the bluish-green colour which the assay takes on being held in the point of the flame with soda on platinum wire. It is found, for the most part, in combination with other cobalt ores, at the Schwarzwald, in Hesse, Saxony, and Thuringia. The Kakochlor has until the present time only been found in the Spitzleite mines.

Silver-cobalt, which was formerly found at the mines in the Schwarzwald, in the Reinerzau, and at Wittich, is a black earthy cobalt with hematite and native silver disseminated throughout it.

FIGS. 12 AND 13.—COBALT-BLOOM.

Crystallises in oblique rectangular prisms, which are generally in combination with truncation of the lateral and basal edges, as in Fig. 13, more frequently in crystalline foliated radiate bundles or crystals, Fig. 12. The specimens figured are from Schneeberg; they were formerly found, however, at the Schwarzwald. It is found in old veins as a product of decomposition of smaltine as an earthy crust, or *red earthy cobalt*, partly mixed with pharmacolite. The colour is a brilliant crimson to scarlet, the lustre is pearly, it is translucent, flexible in thin laminæ, the hardness is = 1·5—2·0 and the sp. gr. = 2·9—3·0. It is arsenical oxide of copper, with 6 equivalents of water, and is similar in composition to the *crocidolite* or blue asbestus, the form of whose crystals it also takes—*i.e.*, it is isomorphous with it. It is found principally with the other ores of cobalt; it occurs very fine at Riechelsdorf in Hesse, and at Schneeberg in Saxony.

PLATE XVII. FIG. 14—17, PLATES XVIII. AND XIX. FIG. 1—10.

IRON ORES.

Iron, undoubtedly the most useful of all metals, is at the same time very generally distributed; it is found not only in all formations, but also in all high mountains, and even in level plains. It is not, indeed, everywhere present in such considerable quantities as to be readily obtained, yet it is nowhere quite absent, as the colours of rocks and soils, and sometimes also the contents of mineral waters, prove. Indeed, when black or red-coloured rocks, red or dirty-yellow coloured soils occur, or when a spring deposits an ochrey-yellow mud, we may be sure that a quantity of iron is present; and it so happens that the ashes of most vegetables, the solid and fluid parts of animals, but especially their blood and flesh, generally contain a considerable amount of iron.

Iron is found native only exceptionally, and then it is usually of meteoric origin. In general it is mineralised by sulphur or oxygen, or combined as an oxide with silicic and other acids; and as it is only the compounds with oxygen that are used for obtaining iron, these are usually called the *iron-ores*. On being heated, they all give, when held in the reducing flame, a slaggy-looking drop, which is attracted by the magnet, and which yields with borax a yellow-coloured pearl, which becomes olive to grass-green on getting cold. It is soluble by acids to a green fluidity

which gives a blue precipitate with ferro-cyanide of potassium, and with tincture of galls a violet precipitate.

Fig. 14—17.—Native Iron and Meteoric Stones.

Native iron may be recognised by its grey colour, crystalline structure, metallic lustre, toughness and malleability; by its hackly or granular fracture, a hardness of 4·5, and a specific gravity of 7·35—7·8. It is infusible before the blowpipe; it burns, however, with emission of sparks, to a black slag, which consists of the protoxide of iron, and, like the native iron, is strongly attracted by the magnet. It occurs very rarely in nature in small laminæ, for the most part accompanied by magnetic ironstone or sulphur pyrites, as, for instance, in the platina sand of the Urals, in the mica-schist of the United States, with sulphur pyrites in the lower *keuper* at Mühlhausen in Thuringia, in the basalt of Antoine, etc. It may be distinguished from the magnetic iron with which it is sometimes associated by its becoming covered with metallic copper when placed in a solution of the oxide of copper, and by its not being friable. Most native iron, however, is meteoric, and, like the meteorolites, has fallen to the earth partly within the period of history; and it is sometimes also disseminated in particles throughout meteoric stones. Blocks of such masses of iron have been known, of from 15 to 30,000 pounds, which have been worked as malleable iron, steel, and made into all kinds of instruments. Thus Pallas found a mass of 1400 Russian pounds on the Jenisei in Siberia; similar, and still larger blocks, have been found at Elnbogen in Bohemia, in North and South America, in Mexico and Chili. Meteoric iron usually contains from 2 to 7 per cent. of nickel, is malleable, of crystalline structure, and of an oblique-angled foliated structure like Fig. 17; it also, for the most part, exhibits only a small quantity of carbon; on the other hand, it not unfrequently contains different, and partly new mineral substances, disseminated throughout it, especially *olivine* (Fig. 16), *schreibersite* (a remarkable compound of phosphuret of iron and phosphuret nickel), etc. There is also stellate meteoric iron, which may be distinguished from the others by its finely granular structure and greater hardness, and sometimes also by its containing nickel. It always contains carbon, however.

Meteoric stones generally fall to the earth in rounded masses in the shape of fiery balls, covered with a black and often glassy crust; they usually enter deeply into the soil, and may not unfrequently be found in a heated state if the observer is near; sometimes they split up in the air, and are scattered in numerous wedge-shaped pieces, so that, in fact, there is an actual shower of stones. Fig. 14, in Plate XVII., represents one of a hundred pieces which fell at Stanneru in Moravia, on the 22d of May 1808, within a circuit of three leagues. It presents an earthy fracture of a light grey colour, in which small grains of magnetic pyrites are observable. Fig. 15 is a polished fragment of a similar meteorolite, in which there is a small amount of nickel-iron, and which fell at Aigle in the south of France. Fig. 16 is a cut fragment of meteoric iron, with many more or less decomposed rounded grains of olivine, which was found in Mexico. Fig. 17 is a piece of pure meteoric iron, of almost a silver-white colour, which, being polished and eaten away, shows the foliated structure of the octahedron, and partly also of the cube. Meteoric iron has been made into all kinds of implements. It is now bought, however, as a curiosity, at very high prices (6s. to 24s. or 28s. an ounce), for the cabinets of naturalists and for collections of minerals. The most perfect collection of the kind is that in the imperial cabinet in Vienna, sometimes along with other meteoric stones; very large specimens are also to be seen in the collections in the *Jardin des Plantes* at Paris, and in the British Museum.

Plate XVIII.—Fig. 1—12.—Sulphuret of Iron.

Fig. 1.—Magnetic Pyrites, Pyrrhotine.

A comparatively rare mineral, which crystallizes in hexagonal prisms, and, as in Fig. 1, generally appears to be striated; small hexagonal tables, laminæ, and crystalline foliated masses of a liver-brown to pinchbeck yellow colour, of greyish-black streak and low metallic lustre, also occur; it is friable, opaque, of uneven fracture, of 3·5—4·5 hardness, and 4·4—4·6 specific gravity. It is simple sulphuret of iron, in combination with one-sixth or one-seventh of bi-sulphuret of iron, is attracted by the magnet, on the matrass it gives off sulphureous vapours, and leaves a black magnetic drop. The finest crystals are found at Kongsberg in Norway, where it occurs with native silver (Plate XIV. Fig. 1), also at Andreasberg in the Hartz, and at Freiberg in Saxony. The foliated variety occurs in large masses at Bodemmais in Bavaria, in Canada, and in Massachussets. Like pyrites, it is used in the manufacture of sulphate of iron and sulphuric acid.

Fig. 2—8.—Pyrites, Iron-Pyrites.

A very widely distributed mineral, of yellow colour, and strong metallic lustre, which gives sparks when struck against steel. The primary form is the cube (Fig. 7), which not unfrequently presents a striation parallel to the edges of the cube; the most usual form is, however, the pentagonal dodecahedron (Fig. 2), or a combination of the same with the cube (Fig. 3). More rarely the broken pentagonal dodecahedron (Fig. 4) appears, and this is sometimes also combined with the cube, at the edges of which three unequal-sided triangles appear. Octahedrons, moreover, occur, which sometimes present drusy surfaces, like Fig. 5, or they have an arborescent arrangement, like Fig. 6; there is also the pentagonal dodecahedron in which the single-edged angles are truncated, so that the icosahedron appears more or less distinctly, as in Plate XVII. Fig. 8. Globular and compact masses also occur, frequently in large quantity, especially in the middle and lower stratified rocks, where pyrites also forms the petrifying medium of ammonites, as in Fig. 8, terebratulæ, and even of wood, and the like. In the specimen mentioned (Fig. 8) not only the shell of *ammonites amalthæus*, but also the whole interior of it, is converted into pyrites, and a small cluster of cubes of this mineral is also firmly fixed on it.

The colour varies between reddish yellow and brass yellow, it is sometimes however converted into brown-red, while a part of the mineral is decomposed and changed into a hydrous oxide of iron. This variety has been called *hepatic pyrites* (from ἧπαρ, *liver*). The metallic lustre is remarkable at least in a fresh fracture, the hardness = 6·0—6·5, the specific gravity 4·9—5·0. The constituents are bi-sulphuret of iron = $\ddot{F}e$, with equivalent of iron (45·74) and 2 eq. of sulphur (54·26). When heated in the retort some of the sulphur is sublimed. On the matrass vapours of sulphureous acid are given off, and there remains at last red oxide of iron. It is dissolved with separation of sulphur by nitric acid.

Pyrites is found in all formations, partly in veins, partly in layers or beds, and partly disseminated. The finest crystals are found at Traversella in Piedmont, where the pieces figured 2—5 were obtained, also in the island of Elba, at Wittich in the Schwarzwald, in England, Norway, Sweden, etc. Pyrites containing silver is found in Hungary, and an auriferous or gold-bearing variety occurs in the neighbourhood of the Urals and of the Alps. When it occurs in abundance it is used for the manufacture of sulphur, and sulphuric acid, sulphate of iron, etc., it is also used as a flux in smelting many silver ores.

Fig. 9—12.—Marcasite, Spear-Pyrites, White Iron Pyrites.

Is distinguished from the foregoing by the form of its crystals, which is primarily a right rhombic prism, and by its colour, which is more inclined to a steel-grey. Besides the primary form, however, truncations of the acute angles frequently occur, as Fig. 10, also aggregations of small rhombic tables, like Fig. 9, twin-combinations of from 3—6 segments of crystals, similar to Fig. 11, oblong octahedrons arising from truncation of the angles, with hemihedral bevelling in part, like Fig. 12, also radiated and stem-like masses, nodules and kidneys, etc., which can very easily be separated so as to form small needles of sulphate of iron. Friable and hard like the preceding ore, the specific gravity generally somewhat smaller (=4·6—4·8). The constituents and the behaviour before the blowpipe as in pyrites; the two minerals, therefore, offer a remarkable example of dimorphism.

It occurs principally in veins and in stratified rocks, but particularly in the neighbourhood of the stone-coal, brown-coal, and in bituminous schists, which, on breaking down, yield alum and sulphate of iron, and are therefore called alum schists. Many of these pyrites contain arsenic, others contain traces of copper, silver, or gold; the first are usually remarkable for their bright yellow colour.

Fig. 13—16.—Magnetite, Magnetic Iron Ore.

Crystallises in regular octahedrons, as in Plate I., Fig. 22, which sometimes appear variously distorted or tabular by extension of a single pair of surfaces, as Fig. 14, or they form twins, as in Fig. 13. Truncations of the edges and angles also occur, and combinations of the octahedron with the rhombic dodecahedron and cube, or simple dodecahedrons, which then exhibit a situation corresponding to the edges of the octahedron, as in Fig. 16. These beautiful crystals are from Traversella in Piedmont, and Figs. 13 and 14 from Pfitsch in the Tyrol. Granular, dense, and sometimes also perfectly compact masses are more frequent. The colour is iron-black, sometimes externally inclined to brown, the streak is greyish-black, and the lustre slightly metallic; the fracture is conchoidal to uneven, the friability considerable, the hardness = 5·5—6·5, so that it gives out sparks with steel, and the specific gravity 5·09. It is attracted by the magnet under all circumstances, and thus may be readily distinguished from franklinite and the chromic ironstone, as well as from hematite. The constituents are protoxide and peroxide of iron = $\dot{F}e\,\ddot{F}e$, consisting of 71·87 of iron, and 28·22 of oxygen. Infusible on the matrass, giving a red oxide in the outer flame; when finely powdered it melts in borax to a grass-green bead, which, in the inner flame, becomes light-green, and in the outer an olive-green passing into yellow. Soluble in heated acids. The compact magnetic iron sometimes contains titanium, and the compact magnetic ironstone is frequently of itself magnetic, so that by its aid artificial magnets may be made. The finest crystals are found in the Zillerthal, and in the Pfitschthal in the Tyrol, at Traversella in Piedmont, in Saxony, Thuringia, Moravia, etc.; the finest beds of compact ore are found at Arendal in Norway, Dannemora in Sweden, also in Moravia, Persia, India, etc.

One of the most valuable of iron ores, which, wherever it occurs in considerable quantity, is smelted for iron, and yields the best bar-iron and steel. The best English steel is manufactured from such Swedish or Norwegian iron.

The *octahedral titanic iron*, *iserine*, etc., externally perfectly similar to the preceding, is a magnetic iron containing more or less titania; when finely powdered and melted with salt of phosphorus, in the inner flame it yields a red glass, which becomes violet, and finally colourless, on the addition of some tin; it is found in small octahedral grains at the Iserwiese in Bohemia, and in the form of sand in many rivers of Auvergne and other volcanic districts.

Fig. 17—21.—Hematite, Specular Iron, Red Iron Ore.

Is found crystallised, foliated, fibrous, scaly, earthy, and compact. The crystals exhibit a strong metallic lustre, and a steel-grey colour. The primary form is a rhombohedron, of which, however, the vertex is usually truncated, as in Fig. 17, so that the rhombohedral octahedron predominates. Combinations of several rhombohedrons with the scalenohedron, like Fig. 18, are more frequent, or hexagonal double pyramids, in the form of a table, like Fig. 19, or groups of hexagonal tables, like Fig. 20; the two latter forms are found especially at St. Gothard, Fig. 17 at Vesuvius, and Fig. 18 in the island of Elba. The streak is a brown-red to a crimson, the fracture uneven to conchoidal, the hardness 5·5—6·5; all the crystallised and compact varieties give sparks with the steel. The specific gravity is = 5·0—5·3. It is readily distinguished from magnetic iron by its stronger lustre, by the red streak and the different form of the crystals, and it is not attracted by the magnet. There are, however, pseudomorphs of the form of magnetic iron, the so-called *marthite*, which

unites in itself the peculiarities of both; they occur in the iron micaceous schist of Brazil. The chemical constituents are peroxide of iron $\ddot{F}e$ = 69·35 of iron, 30·66 of oxygen. There are, however, hematites which contain oxide of titanium, rhombohedral *titanic iron* to which belong, for example, most of the hematites of St. Gothard and the ilmenite of Miask. Many of these contain some protoxide of iron, and are then attracted by the magnet.

The crystallised varieties are called in a general way *specular iron*, the foliated *iron-glance*, and if they form large masses of rock, as in Brazil, *micaceous iron ore*, and *itaberite*, the scaly varieties are called *scaly red iron* or *red iron froth*. When dense and compact, they are called *red iron ore*, and when fibrous, like Fig. 21, *hematite* or *fibrous red iron*, when earthy, *red ochre*. Those containing clay are named *reddle* or *red clay iron*, etc. Before the blow-pipe they all become black and magnetic in the inner flame, in which the argillaceous varieties are melted to a slag; the others are infusible. They are only with difficulty, and after a long time, soluble in acids.

Specular-iron and fibrous red iron belong to the best iron ores, and are smelted for iron wherever they occur in large quantity, as, for instance, in Styria and Carinthia, in Silesia, Bohemia, and Saxony; also at the Harz. The fibrous hematite is used also as a polish for metals, for making marks on stone, and, when reduced to a fine powder, also as a colouring material; reddle is employed in the manufacture of red pencils, and as a common pigment.

PLATE XVIII. Figs. 22 and 23, and PLATE XIX. Figs. 1—6.

Brown Hematite, Limnite.

Is found only exceptionally in crystals and in right rhombic prisms, which are usually bevelled, like Fig. 22. This variety is called *göthite*, or *needle-iron ore*, and if it is in transparent laminæ, *rubin-glimmer;* the scaly, fibrous variety has been called *lepidokrokite*, or scaly-brown iron ore. The fibrous, radiatingly foliated and concentric-fibrous, nodular, clustered, and stalactitic forms, are more frequent; they are of yellowish-brown or dark-brown colour, externally of vitreous lustre, internally silky, like Fig. 23 in Plate XVIII., and Fig. 1 in Plate XIX., which is called fibrous-brown iron ore. These are usually associated with compact or jasper-like brown iron ore, as in Fig. 23. The crystallised varieties only, are translucent to semi-transparent. All have a rusty or brownish-yellow streak, and are brittle. The fracture is uneven or fibrous to splintered, the hardness = 5·0—5·5, the specific gravity = 3·8—4·2. They are not attracted by the magnet. When heated in the retort they give off water, and leave peroxide of iron; before the blowpipe, in the inner flame, they give a black drop, which follows the magnet. In the borax pearl they yield, with frothing up, an olive-green pearl, the same as the other iron ores. In acids they dissolve with difficulty. The elements of the crystallised varieties are the hydrous peroxide of iron = $\ddot{F}e\,\dot{H}$; the fibrous varieties contain three equivalents of water to two of peroxide of iron. As the amount of water, therefore, varies from 10·311 to 14·71, they in general yield so much less iron than the red iron ores, but they belong to the best kind of ores, and therefore, whenever they occur in large amount, they are smelted for iron, as, for instance, at the Harz, in Nassau, Carinthia, Styria, Bohemia, Hungary, in the Schwarzwald, etc.

The *argillaceous brown iron ores* occur principally in four different varieties.

1. *Kidney-shaped clay-ironstone*, in roundish hollow masses, either compact or earthy, of a brown to an ochre-yellow colour, like Fig. 2, and pale yellow streak.

2. *Yellow ochre*, soft, triturable, of a brownish-yellow colour, seen at the outside of Fig. 2.

3. As *pea-iron ore*, or nodular clay-ironstone, in roundish or obtuse-angled granules of compact or concentrically scaly structure, sometimes loosely embedded in yellow clay-iron, sometimes aggregated as a conglomerate in a chalky clay, as in Fig. 3, principally in fissures and clefts or cavities in white Jura-chalk; the bones and teeth of animals of the tertiary and diluvial periods are not unfrequently found imbedded in it, and these may be separated from the pure pea-iron ore by washing, as, for instance, in the Swabian Alps, in the highlands of Baden, etc. There is also another variety found in the Elsass, mingled with the petrifactions of the black and brown Jura.

4. The *granular, lenticular, oolitic clay-iron ore* consists of small grains and nodules of a reddish-brown colour, which sometimes occurs by itself, as in Fig. 4, Plate XIX., and then not unfrequently with small mussels, snails, etc., as, for example, at Aalen and Wasseralfingen in Würtemberg, where these ores are imbedded in layers of from 6—12 feet deep in the lower brown Jura formation; or they are grey to blackish-brown, imbedded in clay or sand marl, and form the so-called iron roe-stone, which, in the upper brown Jura of Swabia and Switzerland, forms considerable layers, and is not unfrequently smelted.

In general, brown argillaceous ironstones yield only from 24—32 per cent. of iron; as they usually occur, however, in considerable quantity, and are easily obtained, and generally yield a very good sort of iron, they are frequently smelted, the more especially as they require only a very slight flux.

Fig. 5.—Spathose Iron, Carbonate of Iron, Siderite, Sphærosiderite.

Crystallizes in rhombohedrons the same as calcite, with which it is isomorphous; the angles according to Briethaupt are 107° 41″. The cleavage is parallel to the primary planes. Truncations of the vertical edges, hexagonal tables, and pyramids also occur, as well as foliated, compact masses and radiated globular forms; the common rhombohedron, like Fig. 5, is most frequent. The original colour is yellowish-white, with a remarkable vitreous to adamantine lustre, which is also seen on the planes of fracture. The crystals are for the most part translucent. By decomposition the mineral becomes brown or black, and the lustre and transparency are lost. The fracture is splintery, the structure foliated, the friability remarkable, the hardness = 3·5—4·5, the

specific gravity 3·6—3·9. The pure spathose iron consists of protocarbonate of iron Fe C, composed of 61·37 protoxide of iron, and 38·63 of carbonic acid; it frequently also contains protocarbonate of manganese, and the carbonates of lime and magnesia. The globular and compact varieties of fibrous or earthy fracture are called *Sphærosiderite*, and the latter frequently form, in the clay schists of the coal formations, considerable beds, which are used for iron, and not unfrequently enclose fishes, sauria, and the remains of plants, as for example in the Saarbrück, at Lüttich, etc. The *black-band* is a similar iron-ore of a steel-grey or coal-black colour, of the appearance of schistic anthracite, containing about 63 per cent of protocarbonate of iron, which has been found in the coal formations of Staffordshire, South Wales, and Lanarkshire, and also at Saarbrück. It also yields a good variety of iron, which is mostly appropriated to the manufacture of steel.

Before the blow-pipe, in the inner flame, the spathose iron ores give the peroxide and protoxide of iron, which is attracted by the magnet. They are soluble in nitric acid with effervescence, and some of the clay which is present is also separated.

The finest crystals of spathose iron are obtained from the mines of Neudorf in the Harz, from Altenberg and Ehrenfriedersdorf in Saxony, and Lobenstein in Vogtland; the compact variety occurs at the Stahlberg in Nassau, at Schmalkalden, and in Styria. These pure spathose iron ores yield principally the white specular iron, so highly valued for the manufacture of steel. The clay sphærosiderites are found almost wherever the coal formations exist, and the mammillary sphærosiderite for the most part in the dolerite of Steinheim at Hanau.

Mesitine-spar is the name which has been given to a combination of equal proportions of protocarbonate of iron and carbonate of magnesia, which occurs in rhombohedral lenticular forms of silky lustre at Traversella and at Duttweiler. *Oligon-spar* is a compound of like equivalents of oxide of manganese and of the protoxide of iron; it is also rhombohedral, and occurs at Ehrenfriedersdorf in Saxony.

Figs. 6 and 7.—Phosphate of Iron.

The combinations of the oxide of iron with phosphoric acid are practically of very little importance, the bog-iron ore only being smelted when it occurs in large quantities, and principally for cast-iron.

Bog-iron ore (Fig. 6) is a hydrous oxide of iron generally containing clay mixed with a phosphate of iron, sometimes found in roundish lenticular forms, sometimes in shapeless masses of a yellowish-brown colour, principally in such situations as where standing water is acting upon ferruginous rocks; and different marshy plants are occasionally found in it, similar to those found in peat-mosses. There are several varieties, distinguished according to the peculiarities of their occurrence, but all of them give a brownish-yellow streak, and contain, in addition to phosphate of iron, water, alumina, silica, and generally a little oxide of manganese. The sandy iron ores are partly in the form of plates, partly cylindrical, and frequently form long cylindrical tubes of 1—8 inches in diameter; besides the elements already mentioned, they generally contain some quartz-sand. They occur pretty frequently in Northern Germany. Bog-iron ore is found in the Pfalz, in Pomerania, Holstein, Sweden, and Russia, sometimes in considerable quantity, so that it is smelted. *Vivianite* or *blue iron earth*, Plate XIX. Fig. 7, crystallises in oblique rectangular prisms, and occurs especially with truncations of the edges, like gypsum, also radiated, foliated, and earthy, of an indigo-blue colour, vitreous lustre, translucent, of distinct foliated structure, of 1·5—2·0 hardness, and 2·6—2·7 specific gravity. It is sesqui-phosphate of iron, with 6 equivalents of water, and melts in the inner flame to a grey lustrous granule of phosphate of iron. Fine crystals are found at Bodenmais in Bavaria, in Cornwall, and in Auvergne. The earthy vivianite is formed in marshes and peat-bogs, and is deposited in the shape of a fine powder in wood, peat, etc. It occurs in Holstein, Swabia, and Silesia, but generally only in small quantities. *Dufrenite* or green iron ore is a dark green and hydrous phosphate of iron, of radiated fibrous structure, of 3·5 hardness, and 3·2—3·4 specific gravity, which is found in botryoidal, nodular, fibrous, and radiated masses, at Johann Georgenstadt in Saxony, Bieber in Hesse, and Schindeloh in Bavaria.

Figs. 8 and 9.—Arseniate of Iron.

The compounds of the oxide of iron with arsenious acid have only a scientific interest, and they are also of but rare occurrence.

The *scorodite* crystallises in rhombic octahedrons, which, as in Fig. 8, are truncated at the angles, and generally bevelled at the basal angles, of vitreous lustre, bluish green colour, of 3·16 specific gravity, and 3·5—4·0 hardness. It is an arseniate of iron, with 4 equivalents of water, and is found especially fine at Schwarzenberg, and Schneeberg in Saxony.

Cube iron ore crystallises in cubes of a light green to an olive green colour (Fig. 9), of vitreous lustre, translucent, of 2·5 hardness, and 2·9—3 specific gravity. It is one-third arseniate of the protoxide, with two-thirds of arseniate of the peroxide of iron and 18 equivalents of water, and occurs principally at Schwarzenberg, and at Freudenstadt in the Schwarzwald.

Before the blow-pipe both ores give off in the reducing flame watery vapours and an arsenious smoke, and at last leave a grain which is attracted by the magnet.

The *pittícite*, or colophony iron, is an amorphous arsenical hydrous oxide of iron, with the appearance and resinous lustre of brown colophony, and marked conchoidal fracture, which is found particularly fine at Graul, near Schwarzenberg, and formerly occurred also at Wheal Sparrow in Cornwall.

Fig. 10.—Sulphate of Iron.

Crystallises in oblique rhombic prisms, of bluish-green colour, vitreous lustre, translucent, of 2·0 hardness, and 1·8—2·0 specific gravity; it is found, however, for the most part in the walls of old mines in stalactitic or botryoidal forms, of crystalline structure when of more recent formation, or in fine needles and efflorescences, and consists of decomposed iron pyrites. It is sulphate

of iron with 6 equivalents, (45·9) of water, of an astringent taste, easily soluble in water, decomposing in the atmosphere, and falling down into a yellowish white powder. It is found in old mines at the Harz, in Saxony, near Schwarzenberg, etc. Sometimes it contains copper, and has then a remarkably fine blue colour. The sulphate of iron is used for black paint, in the manufacture of ink, sulphuric acid, etc., it is usually obtained artificially from vitriol-schists, or from roasted iron pyrites. Fig. 10 is an artificial group of crystals.

Fig. 11—19.—Manganese Ores.

Manganese is a blackish-grey, but friable metal, nearly allied to iron, very difficult of fusion, strongly resisting heat, only slightly magnetic, of 8·01 specific gravity, which loses its lustre in the atmosphere, and does not in nature occur native. Most frequently it is combined with oxygen, more rarely with sulphur, and some of these combinations have a general resemblance to the corresponding iron ores, with which they are also frequently found. All of them, after heating with borax, give an amethyst pearl, and when held in the point of the flame a longer time with soda, a greenish-blue cloudy schlag of manganate of soda, which becomes colourless in the reducing flame. They generally possess a metallic lustre, and specific gravity of 3·7—4·8. The metal manganese has as yet found no application in the arts, but it renders many kinds of iron impure without having any injurious influence on them. On the other hand, the different oxides of manganese are used in making violet, brown, and black enamel colours for glass and porcelain, in the preparation of oxygen and chlorine, for the colouring of green glass, etc.

Sulphuret of Manganese.

Is found in two combinations in nature, in the first place as *manganese blende*, or simple sulphuret of manganese, crystallising in cubes, iron-black, opaque, of slight metallic lustre, at Naygag, in Siebenburg, in Cornwall, and in Mexico; and secondly, as *hauerite*, a bi-sulphuret of manganese, in regular octahedrons, sometimes in combination with the cube or rhombic dodecahedron, as in magnetic-iron, or *franklinite*, Plate XX., Fig. 24, also iron-black passing into reddish-brown, with a brownish-red streak, at Kalinga, not far from Altsohl in Hungary. This latter is amorphous with sulphur pyrites.

Fig. 11—18.—Oxide of Manganese.

They are all recognised by their iron-black colour and metallic lustre, and yield, when heated in a test-tube, more or less oxygen, and with hot nitric acid chlorine, giving more of both the greater the amount of oxygen contained, and therefore most can be obtained from pyrolusite.

Fig. 11.—Hausmannite.

Crystallises in quadratic octahedrons, which may be split perpendicularly to the principal axis, and, as in Fig. 11, for the most part in combination with a second lower quadratic octahedron truncated and bevelled at the acute angles; compact and granular masses are also found. Of slight metallic lustre, and brownish black colour; the streak is chestnut brown, the fracture uneven, the hardness = 5·0—5·5, and the specific gravity = 4·72. Opaque, friable. The constituent elements are equal proportions of the protoxide and of the peroxide of manganese, $\dot{M}n$ $\ddot{M}n$; the composition, therefore, corresponds to those of magnetic iron, not so the form of the crystals however. It is found at Ihlefeld in the Harz, Ilmenau in Thuringia, Schneeberg in Saxony, and like the other ores of manganese, it is principally employed in colouring enamel and glass.

Figs. 12 and 13.—Braunite.

This also crystallises in square octahedrons, which, as in Fig. 12, are truncated at the vertex, or, as in Fig. 13, are in combination with a second more acute square octahedron, and may be split in the direction of the octahedral planes. Iron-black, with brownish-black streak, opaque, of metallic lustre, of 6·5 hardness, and 4·8—4·9 specific gravity. Infusible before the blow-pipe, and otherwise sharing the properties of other ores of manganese. The elements are peroxide of manganese $\ddot{M}n$. It is found at Ilmenau in Thuringia, at Wunsiedel in Bavaria, at St. Marcel in Piedmont.

Figs. 14 and 15.—Manganite.

Crystallises in right rhombic prisms, which, however, are generally truncated at the acute lateral edges, as in Fig. 14, and exhibit marked longitudinal striation, and admit of cleavage in the direction of the short diagonal. Double truncations of the lateral edges, sometimes with single or double bevelling of the basal edges and basal angles, also occur, as in Fig. 15, and in addition, granular and foliated masses. It is brownish-black to iron-grey, opaque, of a high metallic lustre, hardness = 4, and specific gravity = 4·328. It does not give off colour, and may be distinguished from the next ore, with which it is frequently confounded, principally by its greater hardness, brown streak, and stronger lustre. The crystals are also sometimes covered with the hyperoxide of manganese. In the retort it always gives off some water, which is an essential distinction from the two foregoing ores as well as from pyrolusite. The chemical constituents are simple hydrous oxide of manganese, $\ddot{M}n\,\dot{H}$ with 10·19 of water. It is found principally at Ihlefeld, in the Harz, at Ilmenau, in Nassau, Sweden, England, etc., and is generally met with in commerce, mixed up with pyrolusite, under the name of *grey manganese ore*. It yields very little chlorine and oxygen.

Figs. 16 and 17.—Pyrolusite, Grey Ore of Manganese.

Crystallises likewise in right rhombic prisms of 86° 20′ and 93° 40′, which, however, like Fig. 16, are mostly

truncated at the lateral edges and basal angles, and may be split in the direction of the short diagonal. More frequently it occurs in acicular, or in radiated, sometimes foliated, more rarely in columnar or compact masses. Iron-grey, giving off colours readily with an iron-black streak; hardness 2·5—3·0, specific gravity 4·3 to 4·8. Constitution, hyperoxide of manganese $\dot{M}n = 1$ equivalent of manganese (63·36), and 2 of oxygen (36·64). It is changed in the inner flame on charcoal into a red-brown oxide of manganese, and when heated in a retort, besides slight traces of water, it always yields a considerable quantity of oxygen, so that a piece of live wood held before it soon takes fire; it is much the best oxide for the preparation of chlorine, chloride of lime, and chlorate of potash; on the other hand, it has no advantage over the other manganese ores in the preparation of colours for enamels. It is found of superior quality at Ilmenau in Thuringia, at Villingen, at the Schwarzwald, also at the Erzgebirge, in Silesia, Bohemia, Hungary, England, etc.

Fig. 18.—Psilomelane, Compact Grey Oxide of Manganese.

Nodular, botryoidal, reniform, compact, sometimes fibrous or scaly, of dark-grey or bluish-black colour, small metallic lustre, conchoidal fracture, friable, and very hard, with brownish-black streak, hardness = 5·0—6·0, so that it gives out feeble sparks when struck against the steel. Specific gravity 4·0—4·15. The chemical composition is manganate of copper, oxide of manganese, with some potass, to which silicic acid and water are also usually added. Infusible before the blowpipe, in the retort some water is given off, otherwise it has the same relations as the other ores of manganese. It is found generally with pyrolusite, at the localities given under that head, also with red and brown iron-stone, and is frequently smelted along with these.

The *leptonemerz* of Breithaupt is a similar black manganese ore, which consists of oxide of manganese and water; *polianite*, which sometimes resembles it, is on the other hand manganate of copper of 5·5—6·5 hardness; both of them are found at Aue, near Schneeberg, and at Elgersburg in Thuringia.

Wad or *braunsteinschaum* is a dark-brown earthy protoxide of manganese, occurring in loose kidneys or roundish masses, extremely light and rich in water, which it gives off in the retort; it is brown in colour, and exhibits a hardness of 0·5—1·0. It occurs with the other ores of manganese, especially at Westerwald, and at Naila in Bayreuth.

Compounds of Manganese.

The protoxide of manganese has much similarity in its relations to the protoxide of iron, and forms with the acids rose-red coloured salt compounds.

The *red manganese ore* or protocarbonate crystallises in rhombohedrons similar to calcite and spathose iron, of 107° 0′, according to Breithaupt, and therefore has the appearance of a rose-red calcite, translucent; hardness 3·5, specific gravity, 3·4—3·59, and is soluble in acids with effervescence. The constituents are simple carbonate of manganese, composed of 61·73 of the protoxide of manganese, 38·27 of carbonic acid = $\dot{M}n\,\ddot{C}$; it generally contains, however, a little lime, magnesia, and protoxide of iron, in addition. It is found principally at Kapnik in Hungary, and Naygag in Siebenburg, also in Nassau. The so-called *himbeerspath* of Nassau and Schneeberg in Saxony is a calcite containing lime and protoxide of iron, and the manganocalcite is a manganite containing lime, magnesia, and protoxide of iron.

The *Manganese spar*, or *Rhodonite*, is sesqui-silicate of the protoxide of manganese, of a rose-red colour, which occurs partly in crystalline, foliated masses, partly compact or finely granular, like Fig. 19; the former variety may be split in the direction of an oblique rhombic prism, and is almost translucent, of splintery fracture; hardness = 5·0—6, so that it gives faint sparks on the steel; specific gravity 3·5—3·6. It is melted before the blow-pipe to a red pearl, which is blackened in the external flame, and with phosphorus yields a skeleton of silica. It is found at Elbingerode, at the Harz, at Kapnik in Hungary, and in Siberia. The granular variety is applied to all kinds of small objects of art, and takes a beautiful polish.

Lead Ores.

Lead is a bluish-grey, very soft, easily fusible metal, of 11·4 specific gravity, and 1·5 hardness; of bright metallic lustre, but it soon loses this on exposure to the atmosphere, and becomes covered with a grey layer of the suboxide. It melts at 612° Fahr., and evaporates in iridiscent vapours tolerably quickly, in which are carried off other metals also, such as antimony, arsenic, and even some silver. It moreover exercises a solvent power on many other metals, especially on silver and gold, so that these may be separated by it from their various ores, especially if they are first roasted, an operation which in many furnaces is carried on under the name of silvering or eliquation. Lead also serves similar purposes in testing silver ore in small quantities, when the contained lead of liquidation is refined by bone-ashes. Lead crystallises under certain conditions in regular octahedrons, and is found only very rarely native, in small grains of metallic lustre, partly in lead-glance, as for instance at Alston Moor in Cumberland, Carthagena in Spain, in a rock containing lava in Madeira, and also in small globules in a mass of meteoric iron found at Tarapaca in Chili. Most of the lead of commerce is obtained from lead-glance, and a few other lead ores.

The softness and malleability of lead implies a wide application of it to tubes, plates, drains, mouldings, types, etc. One of the principal purposes to which it is applied is the lining of the leaden chambers for the manufacture of sulphuric acid, the pans for boiling alum, etc. It is also used in the manufacture of different surgical and chemical instruments in the soldering of iron railings and posts; in the preparation of litharge, red lead, sugar of lead, white lead, and other preparations; for lead bullets, shot, etc.; as well as for various easily flexible metallic mixtures, especially as moulds for letters, stereotype plates, etc. The lead of commerce is not, however,

generally chemically pure, but for the most part contains traces of antimony, copper, silver, and gold. All preparations of lead are poisonous, and as the oxide of lead forms an ingredient of the glazing of common earthenware, which is usually readily acted on by weak acids, it is necessary to be very careful in this respect.

PLATE XX.

FIG. 1—3.—GALENA, LEAD-GLANCE, SULPHURET OF LEAD.

The primary form is the cube (Fig. 1), which is also of most frequent occurrence. Truncation of the edges and angles (Fig. 2) are also found, as well as regular octahedrons, and combinations of this with the rhombic dodecahedron (Fig. 3 D), cube (H) and pyramidal octahedron (I); twins, dense, foliated, and crystalline granular, and perfectly compact masses also occur; the last-named variety being called *galena*. The colour is lead-grey, sometimes with a black or variegated tarnish, the streak is lead-grey, and it makes a black mark upon paper. The faces of the crystals are not unfrequently striped in clusters, or run together, as it were, and the angles and edges are also sometimes rounded off. The metallic lustre is brilliant, especially in a fresh fracture, dazzling in the finely granular and compact varieties, the fracture is even, the hardness = 2·5, and the specific gravity 7·4—7·6. The composition is simple sulphuret of lead, $\dot{P}b$, composed of 1 equivalent of lead (86·55) and 1 equivalent of sulphur (13·45). There are also zinc, antimony, copper, and silver-lead ores, and part of the sulphur is sometimes also replaced by selenium. The silver-lead ores are only rarely crystallised, being generally finely granular and of lighter colour, the granular lead ores especially are more or less rich in silver. The silver is contained in it as sulphuret of silver, and the amount of silver varies from $\frac{1}{4}$ of an ounce to 3 ounces in the cwt. Compact lead ore usually contains sulphuret of antimony, that containing zinc-blende is recognised by its brownish colour, and that which contains copper by the disseminated yellow points or grains. There are also earthy lead ores, black lead ore, of blackish colour and dazzling appearance. Before the blow-pipe it melts easily and gives off sulphureous vapours; on the charcoal it becomes coated with the yellow oxide of lead, which may be easily reduced to small globules of lead, and the lead may be reduced and evaporated with evolution of white fumes, in iridescent colours, and on cooling the test is covered with yellow needles. Lead is readily beaten out with a hammer. A small amount of arsenic being present may be recognised by its peculiar odour, resembling that of garlic, and a similar quantity of selenium by the odour of horse-radish, while antimony gives a dense, white, inodorous smoke, and a coating on the charcoal, which is easily blown off. The silver in it can be most easily obtained by first reducing the heated lead ore and refining it with bone ashes, by which process the grain of silver is at last left behind.

The tests in the moist way are still more certain, if the reduced grain of lead be dissolved in pure nitric acid, and the silver deposited by common salt. 100 parts of the washed, dried, and melted chloride of silver, contain 75·33 of silver and 24·67 of chlorine. The test may be made shorter if the separation of the chloride of silver be obtained by a filtered solution of common salt, when the amount of silver may be reckoned by the proportion of the precipitate to the solution employed.

Galena is the most widely distributed of lead and silver ores, and is therefore, wherever it occurs in considerable quantities, as, for instance, at the Harz, the Erzgebirge, in Nassau, the Black Forest, etc., smelted into lead. It is found usually in veins or beds, in the primary as well as in the older stratified formations. The finest crystals are found at Clausthal, and Neudorf in the Harz, Tarnowitz in Silesia, Przibram in Bohemia, Derbyshire, etc.

When lead-glance is silverless, and occurs pure, it is brought into commerce as *lead-ore*, and applied to the glazing of earthenware. The lead obtained in the process of refining forms a more or less pure oxide of lead, and is sometimes brought into commerce by itself, sometimes applied to the manufacture of red lead, and sometimes reduced to metallic lead and made into bars; the refined silver remaining behind is finely calcined, and is usually made into bars.

The *weissgiltigerz* is a lead ore rich in silver, and containing sulphuret of antimony, sulphuret of zinc, and sulphuret of iron, and sometimes also copper, which contains 5—20 per cent of silver, and sometimes resembles grey copper ore. It formerly occurred plentifully at Freiberg and Joachimsthal.

The *seleniuret of lead*, of 2·5 specific gravity, similar in appearance to the foliated lead-glance, evolves before the blow-pipe strong vapours of selenium, with the odour of horse radish or rotten cabbage, and gives a yellow bleb, and finally a grain of lead. It is found at Tilkerode and Zorge, also at the Lorenzo mine at Clausthal, etc., in the Harz, where seleniuret of cobalt also occurs. Seleniuret of lead and copper, and of quicksilver and lead, are likewise found at Tilkerode.

The compounds of the sulphuret of lead with sulphuret of copper, and sulphuret of antimony, which have been called *bournonite*, *needle-ore*, and *boulangerite*, also those which consist of sulphuret of lead and sulphuret of antimony, such as *zinkenite*, *plagionite*, *geocronite*, and *jamesonite*, we can only mention by name.

COMPOUNDS OF THE OXIDE OF LEAD.

The compounds of lead with acids have more of a scientific than a practical interest, partly because they only occur in small amount, and partly because they are applied to no special use; on the other hand, a variety of them are very remarkable, partly on account of the beauty and brilliancy of the crystals, partly on account of the rarity of the acids found in combination with them (chromic, molybdenic, and vanadic acids), so that these lead ores form an ornament to collections.

FIG. 4—8.—WHITE LEAD ORE, CARBONATE OF LEAD, CERUSITE.

Crystallises in rhombic octahedrons, with cleavage in

the direction of the planes of a right rhombic prism. The crystals are seldom simple, but mostly aggregated as twins, triplets, or even in combinations of six crystals, like Figs. 4 and 8. These are either hexagonal double pyramids, like Fig. 5, or hexagonal prisms with truncation of the basal edges, like Fig. 6, the latter not unfrequently assuming a tubular appearance, through the extension of the two lateral and terminal planes, or they are grouped in a stellate form as in Fig. 8. The crystals are white, passing into yellowish and grey, generally of strong adamantine lustre, but sometimes, especially if they are acicular, the lustre is resinous or pearly; sometimes they are blackened by sulphuret of lead and of metallic lustre, and they are then known as black lead ore. There are also lead-spars coloured green and blue by malachite and lazulite, which are for this reason called green and blue lead spars; reddish and brown-coloured varieties also occur. The *sulphato-carbonate of lead*, or *lanarkite*, like the sulphate of lead, gives, with soda in the reducing flame, the distinct reaction of sulphur. The fracture is uneven to conchoidal, of strong resinous lustre, the hardness = 3·0—3·5, and the specific gravity = 6·34—6·48. The chemical constituents are simple carbonate of lead, Ṗb C̈, composed of 82 of oxide of lead, and 16 of carbonic acid. Before the blow-pipe it decrepitates and is reduced, whereby the charcoal is coated with yellow oxide of lead. In nitric acid it is soluble with effervescence.

It is found in all situations where lead-glance occurs, frequently as of more recent production, especially fine at Mies and Przibram in Bohemia, Badenweiler in the Schwarzwald, Tarnowitz in Silesia, in England and Scotland, North America, etc., and is usually smelted with the other lead ores.

Fig. 9—11.—Anglesite, Lead Vitriol, Sulphate of Lead.

This likewise crystallises in rhombic octahedrons, but more frequently presents simple and regular forms, like the white lead-ore; the simple rhombic prisms are principally found with truncations of the angles as in Fig. 9, or rhombic tables with truncation of the obtuse angles, as in Fig. 10, or with truncation of the angles and edges, as in Fig. 11. The crystals are distinguished by their high degree of lustre, between adamantine and vitreous, and are frequently set in groups as ornaments. They are colourless, passing into yellow, rarely bluish or greenish, transparent to translucent, of small conchoidal fracture; friable, of 3·0 hardness, and 6·2—6·3 specific gravity.

The elements are simple sulphate of lead, Ṗb S̈, composed of 73·56 oxide of lead, and 26·44 sulphuric acid, with occasional traces of water. It melts before the blow-pipe to a clear pearl, which becomes milky on cooling, and yields in the inner flame a grain of lead. In hot nitric acid it is soluble in small quantity, and without effervescence. When held in the inner flame, on charcoal with soda, the charcoal becomes coated with flour of sulphur, and a grain of lead is separated.

It is found especially at Iglesias in Sardinia, whence the crystals, Figs. 9 and 10 were obtained, at Anglesea in Wales, at Hausbaden near Badenweiler, and Herrensegen in the Schwarzwald, also at the Harz, Westerwald, in Hungary, and Siberia.

The *linarite*, or *cupreous sulphate of lead*, is a sulphate of lead containing the hydrous oxide of copper of an azure-blue colour, crystallising in oblique rhombic prisms, which occurs at Leadhills in Lanarkshire, at the Herrensegen, and at Linares in Spain. The *caledonite* is a sulphate of lead containing carbonate of lead and carbonate of copper, of a bluish-green colour, which crystallises in right rhombic prisms, and also occurs at Leadhills.

Fig. 12—15.—Variegated Lead Ore, Pyromorphite, Mimetite.

Crystallises in hexagonal double pyramids and prisms. The former are in general truncated at the vertex, as in Fig. 14, the latter are sometimes simple and extended, like Fig. 13, sometimes flat and truncated at the basal edges, like Fig. 15; the prisms are also frequently barrel-shaped and striated longitudinally, as in Fig. 12. Besides these, acicular, botryoidal, stalactitic, and reniform aggregations are found. The colour varies from pure, to dirty green, yellow, and reddish-brown; the former is known as green-lead ore, and the latter as brown-lead ore. The lustre is in general slight, varying between vitreous and fatty, the fracture is uneven. Semi-transparent to translucent, the hardness = 3·5—4·0, specific gravity = 7·0—7·2.

The chemical constituents are different in almost every locality, so much so that many, especially of the green ores, consist only of phosphate of lead, others, such as many of the yellow and brown coloured ores, of arseniate of lead, while others are composed of both, but in different proportions, and again others contain some chloride and fluoride of lead, or phosphate and arseniate of lime, and fluoride of calcium, or even some vanadate of lead; the oxides of chrome and silver are obtained in small amount in many varieties. In the same manner, the behaviour before the blow-pipe varies according to their constitution; in general they all melt readily in the inner flame to a globule, which gives off more or less arsenical fumes, and after cooling, becomes milky and covered with planes of crystals. This pearl is observed as a flat hexagonal prism with curved faces, or as an hexagonal lens. By continued blowing the test becomes covered with a yellow coating of lead ashes. Phosphates only are present, and thus the test gives off no fumes, but the flame is coloured slightly greenish. If compounds of chlorine be present, and some protoxide of copper added thereto, the flame takes a fine blue colour. In hot nitric acid it dissolves almost perfectly without effervescence.

The following varieties are distinguished:—

1. *Pyromorphite*, or *green lead ore*, which is generally brownish-green and crystallises in hexagonal prisms, but sometimes appears of a light or yellowish green colour. It consists, in great part, of phosphate of lead, with from 2 to 12 per cent of chloride of lead, and is found principally at the Herrensegen, at Hofsgrund and Badenweiler in the Schwarzwald, at Ems in Nassau, Clausthal in the Harz, in England, Scotland, and Bohemia.

2. *Arseniate of lead*, or *mimetite*. Principally composed of arseniate of lead with some chloride of lead and

fluoride of calcium, and sometimes also with some phosphate of lead. It has also been called *hedyphane*. The finest crystals are found at Joachimsthal in Bohemia, at Caldbeckfell in Cumberland, and at Badenweiler, where it also occurs in botryoidal masses. Generally, it is similar to Fig. 14.

3. *Kampylite*, in curved barrel-like crystals, as in Fig. 12, orange-yellow passing into red and brown; the crystals remarkably curved and bent; principally consisting of arseniate of lead, with chromate, phosphate, and vanadate of lead, some chloride of lead and vanadate of lime. It is found at Alston Moor in Cumberland, and at Badenweiler.

4. *Nussierite*, botryoidal and crystallised, greenish-yellow, of 5·64 specific weight. It is a pyromorphite, which contains chloride of lead and phosphate of lime, and occurs at Nussière, department of Rhone, in France.

Fig. 16.—Wulfenite, Molybdate of Lead.

Crystallises in square octahedrons or in square tables, sometimes with truncation of the basal edges, and is also found in crystalline foliated masses, wax or honey-yellow, passing into reddish and brown, of resinous lustre, translucent, of conchoidal fracture, 3·0 hardness, and from 6·69—6·76 specific gravity. The composition is molybdate of lead = $\dot{P}b\,\ddot{M}o$, consisting of 59·3 oxide of lead, and 40·5 molybdic acid. It melts on the charcoal with decrepitation, becomes partly absorbed, and leaves a grain of lead; with salt of phosphorus it gives a green bead, and is dissolved with difficulty in nitric acid. It is found very fine at Bleiberg in Carinthia, in small tables at Badenweiler, in the Tyrol, Hungary, and North America, and is used for making molybdic acid, and the different molybdic salts, especially the molybdate of ammonia, which is used for the detection of phosphoric and arsenical acids.

Fig. 17.—Red Lead Ore, Chromate of Lead, Crocoisite.

The primary form is an oblique rhombic prism, which generally occurs with truncation of the basal and lateral edges, or foliated, as Fig. 17, sometimes also acicular or compact. Various shades of hyacinth-red, with orange-yellow streak. Of adamantine to vitreous lustre, translucent; of uneven fracture, 2·5—3·0 hardness, and 6·0 specific gravity. It is simple chromate of lead, $\dot{P}b\,\ddot{C}r$, composed of 68·38 oxide of lead and 31·52 chromic acid. It melts on the charcoal with decrepitation, is partly reduced, gives off fumes of lead, and with borax a green glass; with nitric acid a yellow solution is formed. It occurs at Beresowsk in Siberia, and in Brazil.

The *Melanochroite* is sesqui-chromate of lead, of a tile-red colour, and crystallises in right rhombic prisms. It is found with the last-mentioned ore. So is the *Vanquelinite*, which occurs in dark green or brownish needles, and is composed of chromate of lead and chromate of copper.

The pure *red lead ore* is used when reduced to powder as a pigment, and for the manufacture of chromate of potash, and chromate of soda, which find many applications, partly as reagents, and partly as colours and in colour printing. It is mostly obtained from the cheaper chromic iron stones.

Fig. 18—21.—Tin Ores.

Tin is one of the longest-known metals, which, on account of its malleability, white colour, and durable lustre, has from the earliest times been employed in all kinds of household implements. It melts readily, has a hardness of 2·0, and a specific gravity of 7·29; it crystallises in certain conditions, either as regular or as square octahedrons, and occurs native only exceptionally in small granules in the gold-sand of the Urals. The most abundant tin ore is the cassiterite, and it is only obtained from tin-pyrites in small quantity.

Cassiterite, Oxide of Tin, Tin Ore.

Crystallises in square octahedrons, which are, however, usually combined with the square prism, as in Fig. 21, or present further truncation of the lateral and vertical edges, as well as of the basal angles, Fig. 20. Quadratic prisms, with truncations of the basal and lateral edges, are more frequent, like Fig. 18, or twins, which, like Fig. 19, are composed of segments of such crystals. Granular and compact masses also occur, and concentrically fibrous wedge-shaped pieces, the so-called *wood-tin*, Fig. 22. The colour varies from light-brown to black, the streak is somewhat lighter, the lustre being half adamantine and half vitreous; the fracture is uneven to conchoidal; the hardness is considerable, 6·0—7·0, so that it gives off sparks with a steel; the specific gravity is equal to 6·96. The composition is oxide of tin = $\ddot{S}n$, 78·26 of tin and 21·38 of oxygen. It is not easily decomposed, and can only be reduced with difficulty on the charcoal, but more readily if some soda is added, and yet more so with cyanide of potassium. The grain of tin tarnishes the charcoal white, the slag being heated with a drop of cobalt solution, becomes light green. It is not dissolved by acids. The only important tin ore, which occurs principally at Ehrenfriedersdorf, Johann-Georgenstadt, and Geyer in Saxony, Joachimsthal, Bohemia, at St. Austle in Cornwall, in Spain and France, in Malacca and Banca in the East Indies, and is generally melted with the addition of any flux between layers of coal. The fibrous or wood-tin has been found in the alluvial deposits of Cornwall and Mexico.

Tin is used for all kinds of articles of furniture, for the foil of looking-glasses, for lining and coating copper and iron vessels and sheet-iron, for alloys of different kinds, for instance, with copper, as gun and bell-metal, with copper and zinc as bronze and pinchbeck, for the manufacture of tin ashes and the various salts of tin, etc.

Tin pyrites is a compound of sulphuret of tin and sulphuret of copper, which crystallises in cubes, but for the most part occurs in crystalline granular masses of a steel-grey to a brass-yellow colour, and of small metallic lustre. It is almost always mixed with copper or iron pyrites, sometimes also with zinc-blende, and yields on an average about 26 per cent. of tin. It is of such rare occurrence in England, however, as to be of no value as an ore.

FIG. 23—27.—ZINC ORES.

Zinc, or *spelter*, as it is also sometimes named, is a bluish-white metal of 6·862—7·2 specific gravity, which retains its lustre for a long time in the atmosphere, exhibits a crystalline foliated structure, and is tolerably hard and tough at an ordinary temperature. It breaks into pieces under the hammer when cold, but at a temperature of from 212° to 302° Fahr. is very ductile, so that it can be extended into plates and wire, but at higher temperatures it again becomes friable, so that it can be reduced to powder. It crystallises in certain circumstances in rhombohedrons, melts at 773°.6 Fahr., takes fire in the air at a somewhat higher temperature, and burns with a bluish-white dazzling flame; when heated in closed vessels it is distilled. It occurs native only very rarely and by exception, frequently, however, mineralised with sulphur and oxygen. The ancient Greeks were in the habit of forming a bronze-like alloy out of zinc ore and copper, without otherwise knowing the metallic zinc, which was first made known in the sixteenth century by Paracelsus; it had, however, been known for many centuries previous to this by the Chinese. Zinc is the most electro-positive of all the heavy metals, and is therefore chiefly used for galvanic batteries and galvanic precipitates, as it throws down even iron from its solutions. It is used by itself for all kinds of artistic moulds, statues, ornaments, and the like; when rolled out into plates as coverings for roofs, the manufacture of water-pipes, &c., in the fabrication of brass and bronze, for the preparation of sulphate of zinc and other chemicals.

FIG. 23.—BLENDE, SULPHURET OF ZINC.

The primary form is a rhombic dodecahedron, Plate II., Fig. 8, which is, however, usually in combination with the octahedron, as in Plate XX., Fig. 23; octahedrons, tetrahedrons, icosahedrons, and twins, crystalline-foliated, fibrous, compact, scaly, and stellate masses are also found. The crystals are of adamantine lustre, of remarkable foliated structure, and admit of cleavage in the direction of the dodecahedral faces. The colour is light-yellow passing into reddish-brown and black; the streak is lighter; the hardness = 3·5—4, and the specific gravity 3·9—4·0.

Pure *blende* is simple sulphuret of zinc, Żn, composed of 66·90 of zinc and 33·10 of sulphur; all the strongly-coloured varieties, however, contain, some of them sulphuret of iron, others sulphuret of manganese; others also contain sulphuret of lead, and the compact blende not unfrequently has some sulphuret of copper in addition. Before the blow-pipe blende decrepitates, gives off fumes of sulphur and zinc, which on the charcoal leave a yellow tarnish, which becomes white when cold, and, when wetted with a solution of cobalt, appears dark-green at a glowing white heat. When melted with soda in the inner flame, metallic zinc is separated, which then burns. Should the blende contain cadmium, as for instance the stellate blende of Przibram, the zinc tarnish presents a brownish ring.

Blende is a very widely distributed mineral, which occurs in all formations, from the primary rocks to the mussel-chalk. The finest crystals are found at Kapnik and Schemnitz in Hungary; at the Harz and Erzgebirge, where it occurs in large quantity, it is smelted for zinc.

FIG. 24.—OXIDE OF ZINC AND FRANKLINITE.

The *red oxide of zinc* crystallizes in right rhombic prisms, but is only found in crystalline foliated masses (Fig. 24), of a brownish-red colour, translucent, of adamantine lustre, brittle, of 4·0—4·5 hardness, and 5·43 specific gravity, but sometimes also in the form of a white powdery efflorescence. The latter consists of pure oxide of zinc, Żn, the former contains 4—12 per cent. of oxide of iron and manganese. It is easily reduced with soda, and is soluble in acids without effervescence.

Franklinite crystallises in regular octahedrons, with a corresponding arrangement of laminæ, which are, however, for the most part truncated at the edges, as in Fig. 24. It is also found compact or in roundish grains embedded in the red oxide of zinc, at Franklin and Sparta, in the United States. It is iron-black, passing into brown, has a dark-brown streak and slight metallic lustre, is opaque, of conchoidal fracture, 6·0—6·5 hardness, so that it gives feeble sparks on the steel, and a specific gravity of 5·09. The constituents are oxide of tin, protoxide of manganese, and oxide of iron, $\left.\begin{matrix}\dot{Z}n\\\dot{M}n\end{matrix}\right\}$ Fe, in which the iron plays the electro-negative part. It melts before the blow-pipe to a black slag, and on the charcoal gives a zinc tarnish, leaving behind an iron slag containing manganese.

FIGS. 25 AND 26.—CALAMINE, CARBONATE OF ZINC.

The primary form is a rhombohedron of 107° 40′, similar to that of calcite and spathose iron, with a corresponding direction of the laminæ; it occurs in crystalline aggregations, like those in Fig. 25, sometimes also with truncation and bevelling of the vertex, Fig. 26, or also in drusiform, fibrous, foliated, granular masses of a white, grey, or brown colour, generally coloured by hydrous oxide of iron. The streak is always somewhat lighter, the lustre slight, the fracture uneven to conchoidal, the hardness 5·0, the specific gravity 4·4—4·5, the crystals only are translucent.

The pure white calamine is simple carbonate of zinc Żn C̈, consisting of 65·20 oxide of zinc, and 34·80 carbonic acid, and is isomorphous with calcite, spathose iron, brown and bitter spars; the ordinary compact calamine always contains a variable quantity of protocarbonate of manganese and iron, hydrous oxide of iron, alumina and silica, sometimes also a considerable quantity of carbonate of lime.

It dissolves with effervescence in acids, and gives on the charcoal, especially with the addition of soda, metallic zinc, and the tarnish peculiar to it. Many calamines, the Silesian variety, for example, also contain cadmium, and give a reddish-brown ring on the charcoal.

Calamine is the principal zinc-ore, and wherever it occurs in larger quantities, as, for example, at Altenberg, and Brillon in the Netherlands, Wiesloch in Baden, Tarnowitz in Silesia, at the Bleiberg in Carinthia, in Cornwall, Cumberland, Derbyshire, Wales, and Lanarkshire, in Britain, and in North America, it is used for obtaining zinc, as well as for the manufacture of brass.

Zinc-bloom is a carbonate of tin containing water, and occurs as a white incrustation in Carinthia.

Fig. 27.—Silicate of Zinc. Smithsonite.

The primary form is a right rhombic prism, which is, however, for the most part, truncated at the obtuse lateral edges and at the angles, as in Fig. 27. Very complicated crystals are found, which may be distinguished from the carbonate of zinc by their strong metallic lustre and transparency, twins also occur, as well as compact and botryoidal varieties. The colour varies from white and yellow into brown and blackish. The fracture is uneven, the hardness 5·0, the specific gravity 3·38—3·40. The constituents are silicate of zinc with 3 equivalents of water, $\dot{Z}n^3\,\ddot{S}i + 3\,\dot{H}$.

The *Willemite* is an anhydrous silicate of zinc, which crystallises in rhombohedrons and in hexagonal prisms, of 5·5 hardness, and 3·93 specific gravity. It is found with the foregoing at Aachen, Raibl in Carinthia, and Franklin in New Jersey.

Both minerals are employed for obtaining zinc along with the common calamine. *Goslarite* or *zinc-vitriol* is sulphate of zinc with 7 equivalents of water, and crystallises in right rhombic prisms of white and reddish colour; soluble in water, of a metallic, astringent taste; it is found in crystalline stalactites and crusts in old mines, as a product of the decomposition of blende, as, for example, at the Rammelsberg near Goslar, and in Cornwall and Flintshire. Sulphate of zinc is, however, generally produced artificially.

PLATE XXI.

Fig. 1.—Cadmium.

Cadmium is a bluish-white metal, first discovered in the year 1818, which is closely related to zinc, and has a specific gravity of 8·60—8·69; it crystallises in regular octahedrons, is somewhat harder than tin, melts before the blow-pipe, takes fire in the air, and with sulphur gives a fine yellow pigment. It is found mostly in combination with zinc ores.

Greenockite, Fig. 1, is pure sulphuret of cadmium, $\dot{C}d$, consisting of 77·3 of cadmium and 22·51 of sulphur, and is as yet the only known compound of cadmium. It crystallises in hexagonal prisms, which are generally more or less bevelled at one end in combination with two pyramids, as seen in Fig. 1; there are, however, exceptionally also simple prisms. When heated in the retort, it decrepitates, and assumes a carmine red colour. When roasted on the charcoal it gives off vapours of sulphur without melting, and encrusts the charcoal with a reddish-brown oxide of cadmium. Until now it has only been found along with prehnite, in small holes, in porphyritic greenstone, at Bishoptown near Paisley, and a few other Scottish localities.

Fig. 2—6.—Bismuth Ores.

Bismuth occurs native, mineralised by sulphur, as an oxide, and in combination with silicic acid. Most of the ores are readily fusible, and before the blow-pipe give a yellow vapour, which is deposited on the charcoal, and with soda it yields a metallic grain. When dissolved in nitric acid, and mixed with water, it gives a white precipitate of basic nitrate of bismuth.

Fig. 2—4.—Native Bismuth.

Crystallises in cube-like rhombohedrons, as in Fig. 3, of a silver white colour, passing into yellowish and reddish, and of strong metallic lustre; it occurs also in crystalline-foliated masses of rhombohedral foliated structure, as in Fig. 2, as, for example, at Redruth in Cornwall, or streaked like Fig. 4, disseminated, etc. The hardness = 2·0—2·5, the specific gravity 9·73, the fracture foliated, and the friability so great that it is easily reduced to powder. It melts readily in the flame of a candle, and volatilises before the blow-pipe, while it leaves a yellow incrustation on the charcoal. Eight parts of bismuth melted with five of lead and three of tin, give the metallic mixture known as Newton's fusible metal, which melts in hot water under 212°, and is therefore used for moulds of all descriptions. The solution in nitric acid is used as sympathetic ink; the paper is written over with it, and the writing disappears by drying, but is again restored by dipping in water, or by being brought into contact with a solution of sulphur.

It occurs pretty frequently, especially in the primary rocks of Bohemia and Saxony, in France, England, Sweden, and Norway, and was formerly also found in the Schwarzwald.

Fig. 5.—Bismuthine, Sulphuret of Bismuth.

Crystallises in right rhombic prisms or needles, is found also disseminated and compact, crystalline-foliated, etc., of a lead-grey colour, sometimes with a variegated tarnish, brittle, of metallic lustre, opaque, of 2·0—2·5 hardness, and 6·549 specific gravity. The composition is simple sulphuret of bismuth, occasionally rendered impure by a little sulphuret of copper; the latter is found at Schneeberg and Johann-Georgenstadt in Saxony, in Cornwall and Cumberland, the pure bismuthine in Sweden, Hungary, etc.

Fig. 6.—Eulytine, Bismuth-blende.

Crystallises in brownish-yellow pyramidal tetrahedrons of adamantine lustre, like Fig. 6, and twins of the same kind, of 4·0—5·0 hardness, and 5·9—6·0 specific gravity. The composition is essentially silicate of bismuth. It melts before the blow-pipe readily to a brown pearl, and leaves an incrustation of bismuth on the charcoal.

It is found mostly along with bismuth ochre, or earthy oxide of bismuth, of yellowish colour, at Schneeberg in Saxony.

Figs. 7—12.—Uranium Ores.

Uranium occurs in nature only in an oxidised condi-

tion, and even these compounds are very sparingly distributed. The metal has no application in the arts or sciences, and was first discovered in pitch-blende by Klaproth in 1789. It is iron-grey in colour, very hard, not magnetic, difficult of fusion, of 9·0 specific gravity, and crystallises in regular octahedrons.

Fig. 7.—Pitch-blende.

May crystallise in regular octahedrons, but is found for the most part only in botryoidal, globular, and compact forms, in blackish brown, slightly lustrous masses, of greasy to metallic lustre, of conchoidal to uneven fracture, very rarely foliated, so that the laminæ appear to correspond to the planes of fracture. The streak is iron-black, the hardness = 5·5, and the specific gravity = 6·46. The composition is essentially protoxide of uranium $\dot{U}$, in which small proportions of protoxide of iron, oxide of manganese, silica, and sometimes also oxide of lead occurs. Melts before the blow-pipe with borax to a grey glass, and with salt of phosphorus a yellowish green bead.

The most important ore of uranium, which is principally used as a yellow and yellowish-green pigment for painting on glass and porcelain. It occurs not unfrequently in Johann-Georgenstadt, Schneeberg, and Joachimsthal in the Erzgebirge, and also in Cornwall, where it has been sold for £30 a ton.

Zippeite, Uranochre.

Is an earthy lustreless mineral, of a sulphur to orange yellow colour, which, with borax, gives a yellow glass in the outer flame, and a green in the inner.

Uranbloom is a carbonate of urania, which occurs with the foregoing in crystalline flakes of pearly lustre and bright orange yellow colour, especially at Johann-Georgenstadt. In Fig. 8 both minerals are figured, the former at the left and the latter at the right.

Fig. 12.—Uranite.

Crystallises in quadratic prisms and tables, as in Figs. 11 and 12, of remarkable pearly lustre, distinct foliated structure, 2·0—2·5 hardness, and 3·1—3·3 specific gravity. We have (1.) *Uranite*, consisting of phosphate of uranium and phosphate of lime, which occurs in greenish-yellow square tables, especially at Autun in France, Fig. 9; (2.) *Chalcolite*, Fig. 10, consisting of phosphate of uranium and oxide of copper, of emerald-green colour. Both contain 24 equivalents, or 15 per cent. of water. The latter is found chiefly at Johann-Georgenstadt and in Cornwall. In the retort, and before the blow-pipe, both give the reactions of water and of oxide of uranium, the latter variety also gives those of oxide of copper. The specimen figured is from Redruth, Cornwall.

Fig. 13—21.—Titanium Ores.

Titanium is a metal occurring only very sparingly in nature, which was first discovered in 1791. It is brittle, difficult of fusion, hard, almost silver-white, and is sometimes found in combination with nitrogen in burned-out furnaces, in which titanic iron ores have been smelted, crystallised in copper-coloured cubes. Until the present time it has been applied to no particular purpose. The oxygen compounds in which it occurs in nature are the more remarkable, since the oxide of titanium, for instance, is found in three different forms, and is trimorphous; on the other hand, it takes, in many iron ores, the place of the oxide of iron, and thus gives both octahedral and rhombohedral titanic iron.

Fig. 13—15.—Anatase.

Crystallises as an acute quadratic octahedron, Fig. 13; but also occurs in combination with the square prism, Fig. 14, truncated at the vertex, Fig. 15, and exceptionally in square tables of dark brown, reddish and blackish colours, of adamantine to vitreous lustre, translucent, friable, of light streak, 5·5—6·0 hardness, and 3·82 specific gravity. It is oxide of titanium, $\ddot{T}i$, consisting of 60·29 of titanium and 39·71 of oxygen; infusible by itself. When melted with soda it gives a greyish glass, and with borax and salt of phosphorus colourless pearls.

It is found at St. Gothard, in Dauphinée, at the Fichtelgebirge, in Spain and Brazil, and in Cornwall and Devonshire.

Figs. 16 and 17.—Rutile.

Crystallises in quadratic prisms, which are generally striated longitudinally, and exhibit a conchoidal to an uneven fracture, sometimes also, as in Fig. 16, they are truncated at the lateral edges and bevelled at the angles; still more frequently they occur in twins and triplets, as in Fig. 17, or in thin needles, blood-red to hyacinth-red, translucent, of metallic lustre, with brown-red streak, 6·0—6·5 hardness and 4·24 specific gravity. It occurs pretty frequently in the Alps, Switzerland, and the Tyrol, in Carinthia and Styria, in France and Norway; it is also found occasionally in Glamorganshire, in large prisms and fibrous masses at Crianlarich in Perthshire, and at a few other localities in Scotland.

Fig. 18.—Brookite.

Crystallises in right rhombic prisms and tables, mostly truncated at the obtuse lateral edges and at the basal edges, as in Fig. 18, and like the two foregoing ores consists of oxide of titanium. It forms the third rhombic form of the oxide of titanium. It is brownish-red, of adamantine to metallic lustre, of 5·5—6·0 hardness, and 4·13—4·16 specific gravity. Otherwise its relations are the same as the foregoing. It is found at Snowdon in North Wales, at d'Oisans in Dauphinée, at St. Gothard, and Rutherford in North Carolina.

Figs. 19 and 20.—Sphene.

Crystallises in oblique rhombic prisms, which are

mostly truncated at the obtuse angles, like Fig. 19, or at the acute angles, as in Fig. 20, or united as twins and triplets. The colour varies from yellow and green to brown and red, the streak is always lighter; the lustre is half adamantine and half greasy, the fracture is conchoidal to uneven, the hardness 5·0—5·5, and the specific gravity 3·4—3·6. Pure crystals are almost always transparent, and may be cut and polished, so that they are used as precious stones for ornament. The constitution is titanate and silicate of lime. $\dot{Ca}\,\ddot{Ti} + 2\,\dot{Ca}\,\ddot{Si}$.

Sphene melts before the blow-pipe to a yellow-brown glass, and with salt of phosphorus gives a red pearl in the reducing flame. It is found especially at St. Gothard and in the Tyrol; the brown occurs in Saxony, Bohemia, and rarely in Scotland.

Fig. 21.—Ilmenite, Titaniferous Iron.

Crystallises like hematite in rhombohedrons, which are, however, generally truncated at the vertex and at the basal edges. It is iron-black, gives a brown-red streak, exhibits slight metallic lustre, is feebly attracted by the magnet, and consists of oxide of titanium, and the protoxide and the peroxide of iron. It occurs at Ilemengebirge, at Miask, and in small quantities at various localities in the United Kingdom.

Fig. 23.—Tantalum Ores.

Tantalum or Columbium is sparingly distributed in nature, and is only found in an oxidised condition, generally as columbic acid in combination with niobic, pelopic, and tungstic acids, in various one-atom bases, such as the protoxide of iron and manganese, oxide of cerium, lime, magnesia, and yttria, frequently in very complicated relations. Most of these combinations are iron-black, of submetallic lustre, very heavy and hard; the metallic acids mentioned appear to replace each other, so that sometimes one and sometimes another predominates.

The *Tantalite* of Bodenmais, Fig. 23, also known as niobite and columbite, crystallises in right rhombic prisms, which are generally truncated at the lateral edges, as in Fig. 23, or they also exhibit truncations of the basal angles or edges. It is iron-black, of dark-brown streak, and feeble metallic lustre, opaque, of 6·39 specific gravity, and 6·0 hardness. It consists principally of the niobate and pelopate of the protoxide of iron; that from Tamela in Sweden is principally tantalate of the protoxides of iron and manganese; the tantalites of Finbo and Broddo contain in addition 8 to 16 per cent of oxide of tin.

Fig. 22—24.—Wolfram, Tungsten.

Wolfram or tungsten, likewise, only occurs in an oxidised state in nature, and generally as an acid. The compounds are recognised by their high specific gravity, and until now have only been noticed in chemistry.

Wolfram crystallizes in right rhombic prisms, which, however, are generally variously truncated at the basal and lateral edges, and also at the basal angles, as in Fig. 22, of weak metallic lustre, iron-black colour and brownish-black streak. The fracture is uneven, the hardness = 5·0—5·5, the specific gravity 7·1—7·4. Twins occur frequently, sometimes also compact foliated masses, the crystals presenting very distinct horizontal striation.

The elements are tungstate of the protoxide and peroxide of iron.

Before the blow-pipe it melts to a grey metallic globule; with borax it gives a greenish, in the inner flame with salt of phosphorus, it gives a red glass, and with soda in the point of the flame a blue enamel. It is soluble in hot nitric acid, by which the tungstic acid is separated as a yellow powder. It is found in the tin-ore mines of the primary formation, also at Neudorf in the Harz, in Styria, England, and France, and is used in the preparation of tungstic acids and its salts.

Fig. 24.—Tungsten, Scheelite.

Crystallises in square octahedrons, with corresponding laminated structure, of greyish or yellowish white colour, vitreous to adamantine lustre, translucent, of 4·0—4·5 hardness and 6·0—6·1 specific gravity. It is tungstate of lime $\dot{Ca}\,\ddot{W}$, and is soluble in hot nitric acid. It melts with difficulty to a translucent glass, gives a green pearl in the inner flame with salt of phosphorus, which on cooling becomes blue. It is found in beautiful crystals at Zinnwald and Ehrenfriedersdorf in the Erzgebirge, in England, France, North America, etc., sometimes with tungstate of lead, frequently in very large crystals, rarely in compact foliated masses, which may be at once recognised by their remarkable specific gravity.

PLATE XXII.

Figs. 1 and 2.—Molybdenum Ores.

Molybdenum was discovered by Scheele in 1778; it is silver-white, hard, ductile, difficult of fusion, of 8·6 specific gravity, and does not occur native, but only in combination with sulphur or oxygen.

Molybdenite, sulphuret of molybdenum, crystallises sometimes in hexagonal prisms, like Fig. 2. It is found, however, more frequently in foliated and scaly masses, as in Fig. 1, of bluish or lead-grey colour, and remarkable metallic lustre. It is opaque, flexible, readily gives off colour like graphite, and is unctuous to the touch, of 1·0—1·5 hardness and 4·5—4·6 specific gravity. The composition is bi-sulphuret of molybdenum $\ddot{Mo}$. Before the blow-pipe it gives off sulphur, and burns gradually, leaving a deposit of molybdic acid.

It is found in the tin mines of the Erzgebirge, Salzburg, Sweden, and Norway, in Cornwall, Cumberland, Argyleshire, and other Scottish localities, and in North America.

Molybdine is found as a sulphur-yellow earthy crust, sometimes with molybdenite, as in Fig. 1, and is generally a molybdic acid, rendered impure by oxide of iron, con-

sisting of one equivalent of molybdenum and three equivalents of oxygen.

Figs. 3 and 4.—Chrome Ores.

Chromium was discovered by Buckland in 1797, and forms a greyish passing into a tin-white, friable, non-magnetic metal, difficult of fusion, and of 5·9 specific gravity. It only occurs in nature in combination with oxygen; most frequently the combinations are with the protoxide of iron and oxide of lead.

Chromic iron-stone, octahedral chrome ore, crystallises in regular octahedrons, like Fig. 4, or in compact granular masses of an iron-black colour, as in Fig. 3, of slight metallic lustre, uneven fracture, 5·5 hardness and 4·4—4·5 specific gravity, opaque and friable; it is chromate of iron $\dot{F}e\,\ddot{C}r$, in which, however, part of the protoxide of iron is sometimes replaced by magnesia or protoxide of manganese and the oxide of chrome, by alumina or oxide of iron. It is not magnetic, but becomes so in the reducing flame. It is soluble with difficulty in borax, and gives an emerald-green pearl. It is found at Kraubat in Styria, Röraas in Norway, Baltimore in North America, at Nantes in France, in Sweden and in Scotland, sometimes in considerable masses, and is principally used for the preparation of chromic acid and its compounds, as well as the oxide of chrome, which is generally applied to glass and porcelain painting.

Chrome Ochre is an apple-green earthy encrustation, which sometimes occurs with chromite, as in Fig. 3, and which also yields an emerald-green glass with borax. It is for the most part an oxide of chrome $\ddot{C}$, rendered impure by silica and alumina.

Fig. 5—10.—Antimony Ores.

Antimony is a metal which not unfrequently occurs in nature, native as well as in combination with sulphur or oxygen, sometimes also with other electro-positive metals, gold and silver for instance, it takes the electro-negative part of the sulphur. All its compounds before the blow-pipe give a white inodorous vapour, which stains the charcoal white, and is easily blown off; the oxides give a colourless pearl with borax.

Fig. 5.—Native Antimony, Stibium.

Crystallises in rhombohedrons, which are sometimes truncated at the basal edges, like Fig. 5; more frequently it is found in crystalline foliated masses, which may be split in the direction of the rhombohedron. It is tin-white, friable, of strong metallic lustre, opaque, of 3·0—3·5 hardness and 6·6—6·7 specific gravity. It melts very readily on the charcoal, and evaporates even while cooling; and the test is also covered with white oxide of antimony. Sometimes it contains traces of arsenic, silver, and iron; the first may be recognised by the odour given off in heating, and the two others remain behind on the charcoal. It is readily soluble in nitric acid, and the solution gives an orange-yellow precipitate with sulphuretted hydrogen. It is found only sparingly at Andreasberg in the Harz, Przibram in Bohemia, and Allemont in France. The metal antimony is principally used in letter-founding and stereotyping, and in several alloys; it is, moreover, used for all kinds of chemical apparatus and various colours, and the metal is for the most part obtained from grey antimony glance, or antimonite. In former times it played a considerable part in alchemy, the compounds with sulphur having been known much earlier, although the metal was first discovered in the fifteenth century. The Chinese have also employed it from a very early period in combination with copper, tin, and zinc, for the manufacture of the alloy known as *tutenague* or *white copper*.

The application of antimony to these alloys depends principally on the peculiarity it possesses of making other metals hard, and at the same time easily melted.

Fig. 6—8.—Antimonite, Stibine, Grey Antimony Glance, etc.

The primary form is a rhombic octahedron, which, however, is for the most part in combination with truncation of two basal edges and basal angles, as in Figs. 6 and 7; yet more frequently it is found radiated in bundles, like Fig. 8, or foliated, granular, etc. The crystals are frequently curved and striated horizontally, like Fig. 7; iron to lead-grey, of metallic lustre, iron-grey streak, but little friable, opaque, of 2·0 hardness and 4·5—4·7 specific gravity. Generally it leaves a mark on white paper. The composition is sesqui-sulphuret of antimony $\ddot{S}b$, consisting of 72·8 antimony and 27·2 of sulphur; occasionally it contains traces of arsenic, which may be recognised before the blow-pipe by the peculiar odour given off. It melts readily, and burns with a bluish flame, gives off white fumes, and is entirely consumed.

It is found principally at Wolfsberg in the Harz, Chemnitz and Schemnitz in Hungary, Przibram in Bohemia, Braunsdorf in Saxony, and in many other localities. It is the most important of the antimony ores, from which most of the other preparations of antimony are obtained. It is also used in medicine.

Fig. 9.—Red Antimony Ore, Kermesite.

Crystallises in oblique rhombic prisms and needles; more frequently, however, it is found in cherry-red bundles, and capillary crystals of adamantine lustre, as Fig. 9, radiated, capillary, &c. It is very soft, 1·0—1·3, sectile, flexible, and gives off colour, of 4·5 specific gravity, and cherry-red streak. The constituents are 1 equivalent of oxide of antimony and 2 eq. of the sesqui-sulphuret of antimony. In the retort reddish sulphuret of antimony is sublimed, and there remains behind oxide of antimony; on the charcoal it fuses readily, and volatilises with a sulphurous odour.

Fig. 10.—Oxide of Antimony.

This occurs in nature in two different forms, namely,

in regular octahedrons, and in right rhombic prisms. The *octahedral oxide of antimony* or *senarmontite*, crystallises in regular octahedrons, as in Fig. 10, of remarkable adamantine lustre, 2·5 hardness, and 5·3 specific gravity, and consists of 2 equivalents of antimony = 84.32, and 3 equivalents of oxygen = 15·68; it melts before the blow-pipe, is reduced and volatilises; with borax it gives a greyish-white pearl.

The prismatic *white antimony*, also known as *antimony-bloom* and *valentinite*, crystallizes in right rhombic white plates of pearly lustre, which are translucent, and possess a hardness of 2·5—3·0, a specific gravity 5·5—5·6, and are otherwise like senarmontite. Senarmontite has as yet only been found in the province of Constantine in Algiers, and at Perneck in Hungary; it occurs in great masses, however, in Constantine; Valentinite, on the other hand, is only found very sparingly at Przibram, Bräunsdorf, etc.

The *antimony ochre* forms a yellowish, earthy encrustation, which is principally found as a product of decomposition, in the form of a yellowish efflorescence on antimonite, and is a mixture of antimonious acid, oxide of antimony and water; it has not been applied to any purpose.

Fig. 11—20.—Arsenic Ores.

Arsenic is a friable metal which has been long known, and which is allied to the metalloids by its electro-negative properties, and not unfrequently occurs native as well as in combination with sulphur and oxygen, and also frequently with other metals, such as silver, antimony, copper, nickel, cobalt, etc. Most of its compounds, especially those with oxygen, are very poisonous, and as it is easily oxidised, all its compounds are in general hurtful to the animal frame. All ores of arsenic before the blow-pipe give, at least in the inner flame, a strong, repulsive odour of garlic or phosphorus, and a white fume, which is only deposited on charcoal in small quantity, and is easily volatilised. When heated in a tube they yield partly metallic arsenic, partly sulphuret of arsenic, and partly sublimed arsenious acid.

Fig. 11.—Native Arsenic.

Crystallises in rhombohedrons like antimony; it is found, however, more frequently compact or amorphous, of a curved scaly structure, and of finely granular to smooth fracture. The colour is tin-white to iron-grey, the metallic lustre slight, but in a fresh fracture easily recognised, as seen in Fig. 11; it also tarnishes readily with a grey efflorescence, which in the streak, however, exhibits metallic lustre. The hardness = 3·5, the specific gravity = 5·7—5·9. Like all metalloids and electro-negative metals it becomes electro-negative by rubbing, volatilises before the blow-pipe with evolution of a peculiar odour, and sublimes in the retort. It is dissolved by nitric acid, and changed into arsenic acid. It is found at Andreasberg, Freiberg, Schneeberg, and Joachimsthal, in Hesse, Styria, France, in Cornwall, etc. The specimen figured (Fig. 11) presents the curved scaly aggregation, and is from Andreasberg.

Arsenic is used in casting shot, for the preparation of arsenious acid or white arsenic, and of red and yellow arsenic.

Fig 12—14.—Orpiment, Yellow Sulphuret of Arsenic.

Crystallises in right rhombic prisms, which, however, mostly occur with truncations of the obtuse basal angles and acute lateral edges, as in Figs. 13 and 14, or in crystalline-foliated masses, with longitudinal striation and remarkable pearly lustre; also efflorescent and disseminated. The colour is citrine to orange-yellow, the streak light-yellow, the hardness 1·5—2·0, the specific gravity 3·48—3·50.

The composition is sesqui-sulphuret of arsenic $\dddot{As}$, consisting of 2 equivalents of arsenic (60·90), and 3 equivalents of sulphur (39·10). Sublimes in the retort, and is completely consumed on charcoal with a white flame, and giving off fumes of sulphur and arsenic. It is soluble in nitric acid and caustic ammonia. It occurs principally at Kapnik and Moldavia, in Hungary, Fig. 14, and as a volcanic product in the Solfatara near Naples, and in other localities, and when finely powdered it is used as a pigment under the name of golden paint, and in dyeing in the preparation of the cold vats. Most of the orpiment of commerce, however, is produced artificially by heating ores containing arsenic; it contains also, for the most part, some arsenious acid, and has therefore a poisonous influence on the animal organism. The same thing is true as regards realgar.

Figs. 15 and 16.—Realgar, Red Arsenic.

Crystallises in oblique rhombic prisms, which, however, are for the most part truncated at the lateral edges, as in Fig. 16, or also at the basal edges, as in Fig. 15, and present a foliated structure corresponding to the primary form. It also occurs in capillary, disseminated, compact, and earthy forms.

The colour is light aurora-red passing into orange-yellow, the streak is orange-yellow. The crystals are readily decomposed by the admission of light, especially at the angles and edges; the vitreous lustre and transparency are also lost at the same time, and they become tarnished by an orange-yellow layer. The hardness is = 1·5—2·0, the specific gravity 3·55—3·60. It is simple sulphuret of arsenic $\acute{As}$, composed of 70·03 of arsenic and 29·97 of sulphur. It behaves before the blow-pipe, and with nitric acid, like orpiment. It also occurs in the same localities, and is applied to similar purposes.

Fig. 17.—Mispickel, Arsenical Pyrites.

Crystallises in right rhombic prisms, which sometimes occur single and sometimes as twins, frequently with truncation of the obtuse angles, as in Fig. 17; compact, granular, and foliated masses are also found. The colour is silver-white, sometimes passing into iron-grey, the lustre

is a brilliant metallic, but occasionally it has a greyish tarnish. The hardness = 5·5—6·0, so that it gives sparks with the steel, while at the same time the arsenical odour may be perceived. The fracture is uneven and it may be easily reduced to powder.

The elements are bi-arseniuret of iron and bi-sulphuret of iron $Fe\,S_2 + Fe\,As_2$. It frequently contains silver. On charcoal it gives off arsenical fumes, and melts readily to a metallic globule. With soda it gives flour of sulphur. When heated in a tube red sulphuret of arsenic is sublimed, and afterwards some metallic arsenic, and grey sulphuret of iron remains as residue.

There is a sulphurless arseniuret of iron of similar crystalline relations, colour, and appearance, which may be distinguished by its greater weight (7·2—7·3). It is a bi-arseniuret of arsenic, which sublimes metallic arsenic in the retort, and does not give flour of sulphur with soda. This variety occurs at Reichenstein, in Silesia and Schladming, in Styria; the other is much more abundant, and is found especially at the Erzgebirge and the Harz.

Fig. 18.—Arsenious Acid, White Arsenic.

This is found in regular octahedrons of adamantine lustre, Fig. 18; occasionally also in tetrahedrons, acicular, and as an earthy or crystalline efflorescence. Colourless, of 3·0 hardness, and 3·6—3·7 specific gravity. The crystals consist of pure arsenious acid $\ddot{A}s$, composed of two equivalents of arsenic (= 75·81) and three of oxygen (= 24·19). It volatilises on the charcoal, giving off its peculiar odour, and sublimes in the retort. It is soluble in water; the solution gives a golden yellow precipitate with sulphuretted hydrogen, which is again soluble in caustic ammonia.

It is found in small quantity, generally as a product of decomposition, or of the action of fire, arising from other arsenical ores, at Bieber in Hesse, Andreasberg, Mariakirch, etc. Much finer crystals are formed in roasting many of the ores of arsenic. It is the most active poison of the mineral kingdom, but is mostly produced artificially, and is then brought into commerce as white arsenic.

Figs. 19 and 20.—Pharmacolite, Arseniate of Lime.

Crystallises in oblique rectangular prisms, which, however, are for the most part combined with truncation of the lateral and basal edges, as Fig. 19. It also occurs radiately foliated, capillary, in bundles, botryoidal, or as a pulverulent encrustation, like Fig. 20. White passing into reddish, occasionally coloured peach-blossom-red by arseniate of the oxide of copper, of pearly lustre, translucent, of 1·0—1·5 hardness and 2·4—2·6 specific gravity. The composition is simple arseniate of lime, with six equivalents of water. In the retort it gives off water, and when melted distributes on the charcoal arsenical fumes and a residue of white encrustation. It is soluble in nitric acid without effervescence, and is insoluble in water. There is also a magnesian pharmacolite of similar appearance, which has been called *picropharmacolite*. The latter is found at Reichersdorf in Hesse, the former at the Schwarzwald, the Harz, Erzgebirge, etc., finest in old mines, where the lode contains calcite, as a product of decomposed cobalt ores, containing arsenic.

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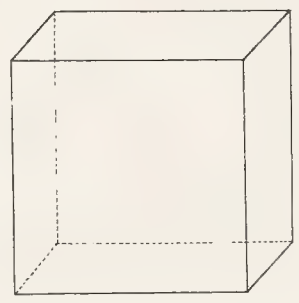

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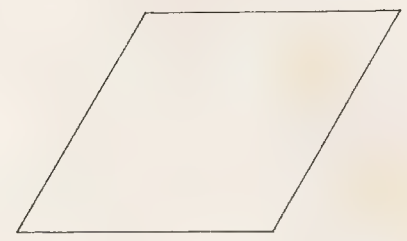

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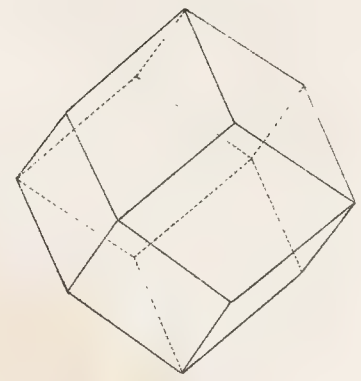

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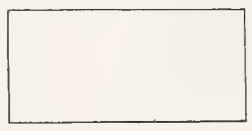

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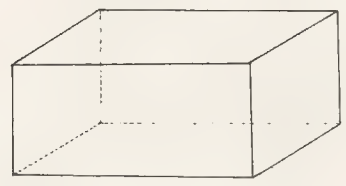

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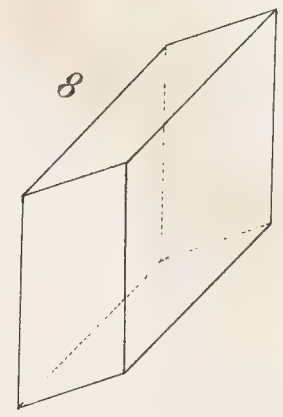

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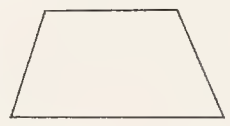

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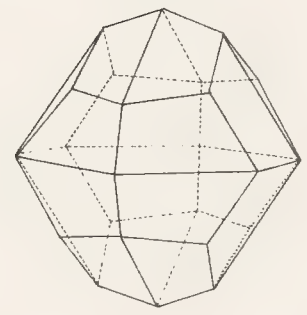

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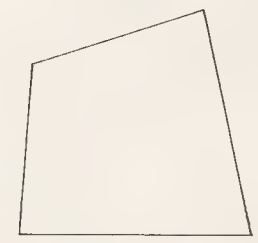

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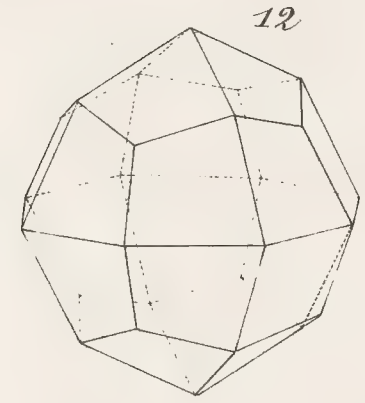

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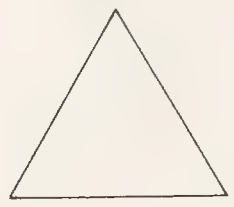

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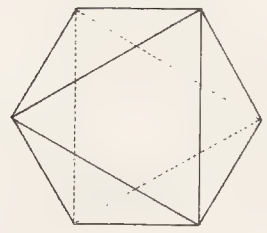

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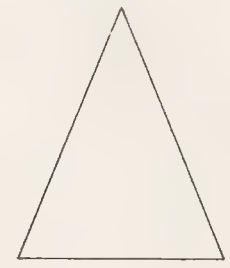

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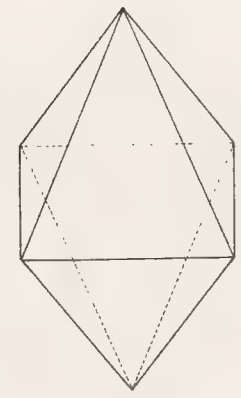

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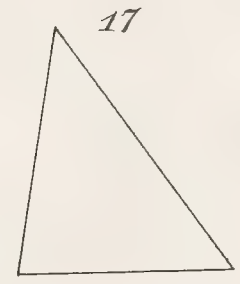

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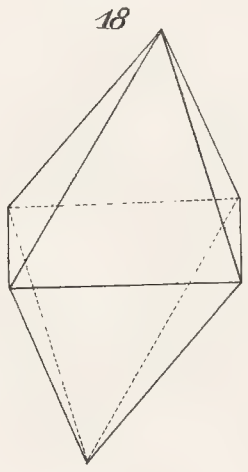

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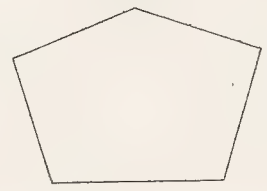

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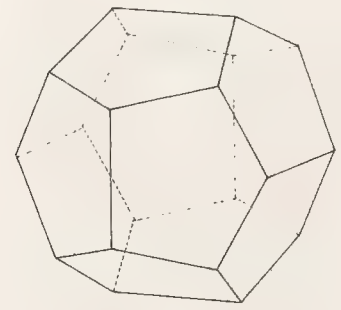

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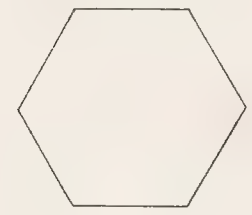

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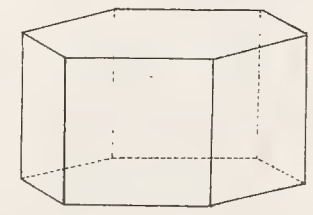

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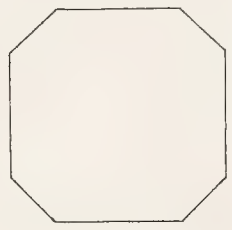

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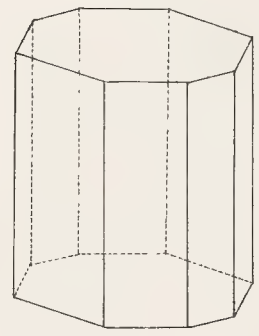

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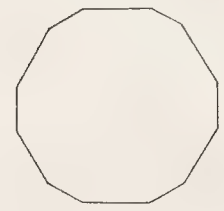

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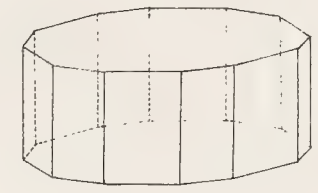

PLATE A.

FIGS. 1—26.—PLANES OF CRYSTALS AND SEPARATE CRYSTALLINE FORMS.

1. *Square*, or face of a cube ; an equilateral rectangular parallelogram.
2. *Cube*, or square prism, contained in six equal square sides.
3. *Rhombus*, an equilateral oblique-angled parallelogram.
4. *Rhombic dodecahedron*, or *granatoid*, bounded by twelve equal rhombic planes.
5. *Rectangle*, an unequal-sided parallelogram, having a right angle.
6. *Rectangular prism*, or right rectangular prism, bounded by six rectangles, whereof every opposite two are equal.
7. *Rhomboid*, an unequal-sided oblique-angled parallelogram.
8. *Oblique rhomboidal prism*, contained in six rhomboids, of which every opposite two are equal.
9. *Trapezium*, unequal-angled quadrilateral with two parallel sides.
10. *Icositetrahedron*, bounded by twenty-four trapezium-like planes.
11. *Trapezoid* or *deltoid*, a quadrilateral with two pairs of equal sides.
12. *Trapezoid* or *deltoid four-and-twenty-faced-solid*, or *leucitoid*, contained in twenty-four equal trapezoidal planes.
13. *Equilateral* or *regular triangle*.
14. *Regular octahedron*, enclosed in eight equal equilateral triangles.
15. *Isoceles triangles*, with two equal sides.
16. *Quadratic octahedron*, or tetragonal octagon, contained in equal isoceles triangles.
17. *Scalene*, or *unequal-sided triangle*.
18. *Rhombic octahedron*, contained in eight equal scalene triangles.
19. *Pentagon*, bounded by five sides, of which one is larger than the other.
20. *Pentagonal dodecahedron*, surrounded by twelve equal pentagons.
21. *Hexagon*, regular, contained in six equal sides, which cut each other at equal angles.
22. *Hexagonal prism*, regular, with two regular hexagonal basal planes, and six equal, rectangular lateral planes.
23. *Symmetrical octagon*, with alternate equal sides and equal angles.
24. *Octagonal prism*, the terminal planes, as in Fig. 23 ; the lateral planes being right angles.
25. *Dodecagon*.
26. *Dodecagonal prism*.

PLATE B.

Figs. 1—10.—Modifications of Crystalline Planes, Combinations, Axes, and Optical Phenomena.

1. *Curved planes of the hexakis-octahedron*, or forty-eight-faced solid, as they occur in the diamond.
2. *Striation*, or *striping of the planes of the cube* in the direction of two parallel edges, as is occasionally seen in pyrites.
3. *Drusy* or *crystalline planes* of the octahedron.
4. *Drusy surface of the cube*, as it sometimes occurs in fluor-spar and lead-glance.
5. *Vertical striation of the hexagonal prism*, united above with the rhombohedral planes, as is often seen in tourmaline.
6. *Horizontally striated lateral planes of the hexagonal prism*, as they occur not unfrequently in smoky topaz and rock-crystal especially. The pyramidal terminal plane and the hemihedral truncated plane of the lateral angles are smooth.
7. *Combination of the cube* P *with the octahedron* O, or truncation of the cube at the edges.
8. *Combination of the cube with the rhombic dodecagon*, the planes of the cube are marked P, those of the dodecahedron D, right truncation of the edges of the cube.
9. *Combination of the cube with the pentagonal dodecahedron*, or oblique truncation of the edges of the cube.
10. *Truncation or sharpening of the angles of the cube*, the planes of truncation are placed on the planes of the cube, combination of the cube with the leucitoid.

Figs. 11—16.—Axes of Crystals.

11. *Cube with three equal axes cutting each other at right angles*, which are indicated by dotted lines, and connect the central points of opposite planes.
12. *Axes of square prism;* the principal axis is greater than the two equal horizontal axes, all three are perpendicular to one another.
13. *Axes of the right rhombic prism;* the three axes are perpendicular to one another, and are of different lengths; the principal axis connects the central points of the basal planes, the horizontal axes those of the lateral edges.
14. *Axes of the oblique rhombic prism;* all the three axes are unequal, the two secondary axes are perpendicular to one another, the principal axis is perpendicular to one of these, and oblique to the other.
15. *Axes of the oblique rhomboidal prism;* all the three axes are unlike, and are at oblique angles to one another.
16. *Axes of the rhombohedron;* the principal axis connects the terminal angles, the three horizontal axes connect the central points of the lateral edges, and lie in a plane, which is perpendicular to the principal axis.

Figs. 17—21.—Optical Phenomena of Crystals.

17. Represents a bit of Iceland *double refracting spar*, which lies on a sheet of paper provided with two concentric rings; both of the rings appear doubled in consequence of the double refraction of rays, and they appear darker where they cover each other. By rotation of the prism, the images are displaced in various ways, and they are coincident so soon as the eye is in the direction of the principal axis (optical axis).
18. *Iridescent rings of colour*, with a dark cross, as seen in double refracting spar, and in all uni-axial crystals when placed in polarised light, as for instance in tourmaline plates; the plates are cut parallel to their axis, and lie crossed. The double-refracting spar is cut perpendicularly to the principal axis.
19. *Iridescent rings*, with a white cross, as they appear in crystals with one optical axis when in tourmaline plates, if the plates lie parallel; all the colours here are complementary to the corresponding parts in fig. 18.
20. Appearance of the *colours presented by crystals with two optical axes* (as salpetre) in polarised light, when the crystal is cut perpendicularly to the middle line (the line dividing into two equal parts the angle of the two optical axes), and laid between the crossed plates of tourmaline, provided that the plane of the optical axis is coincident with the plane of rotation of one of the tourmaline plates.
21. *System of rings of bi-axial crystals*, when the plane of the two optical axis is at an angle of 45° with the plane of revolution of both tourmaline plates.

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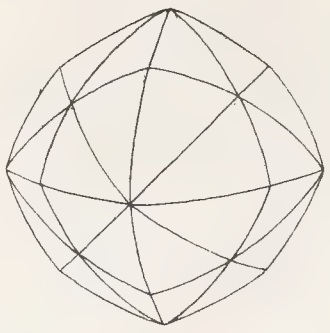

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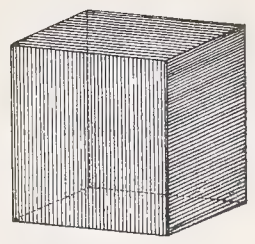

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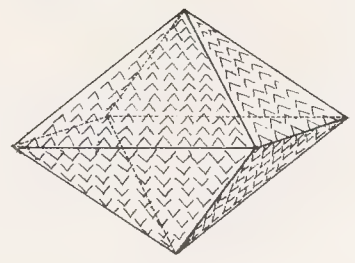

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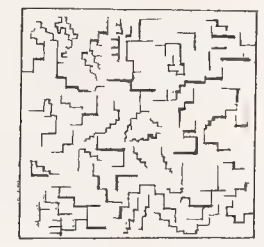

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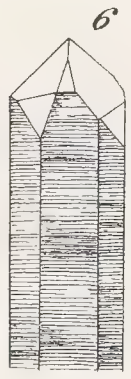

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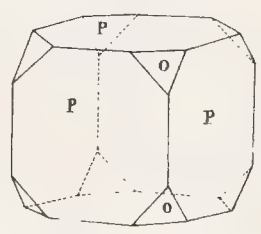

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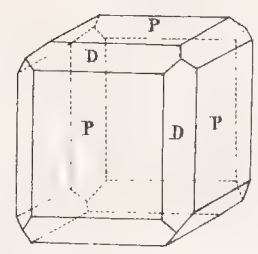

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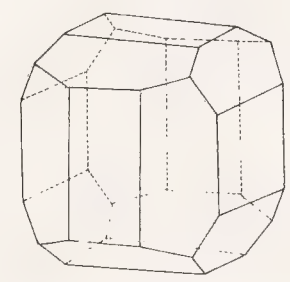

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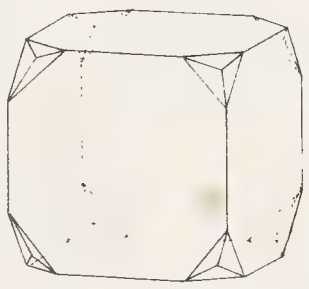

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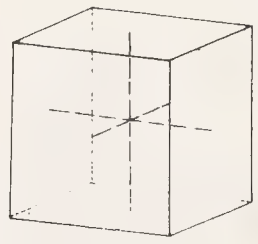

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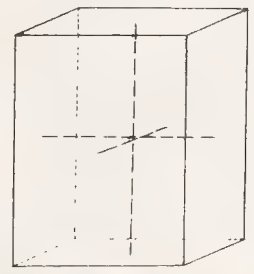

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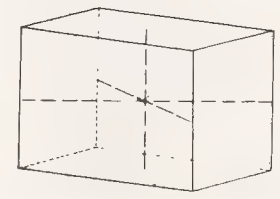

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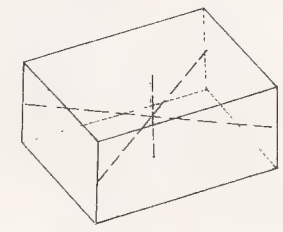

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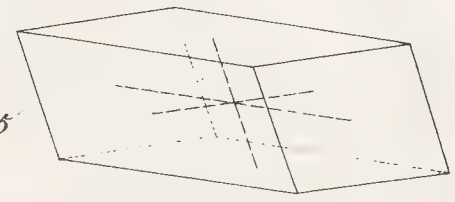

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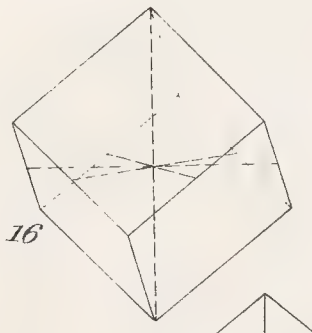

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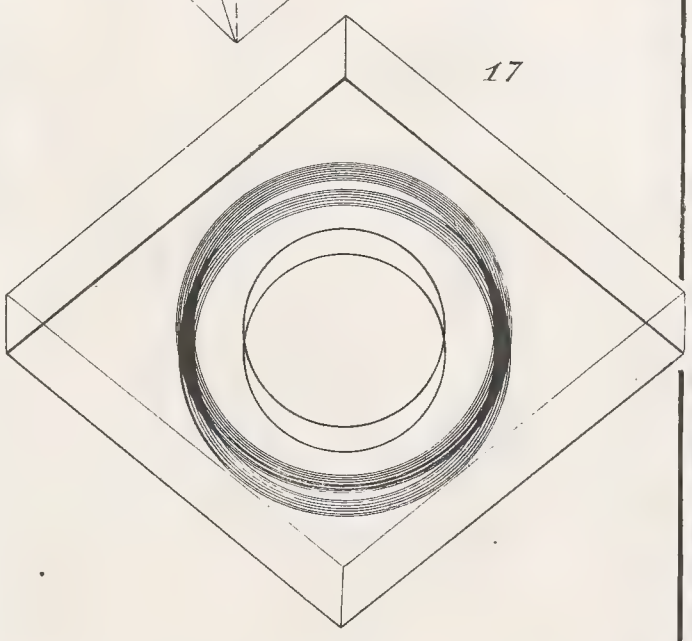

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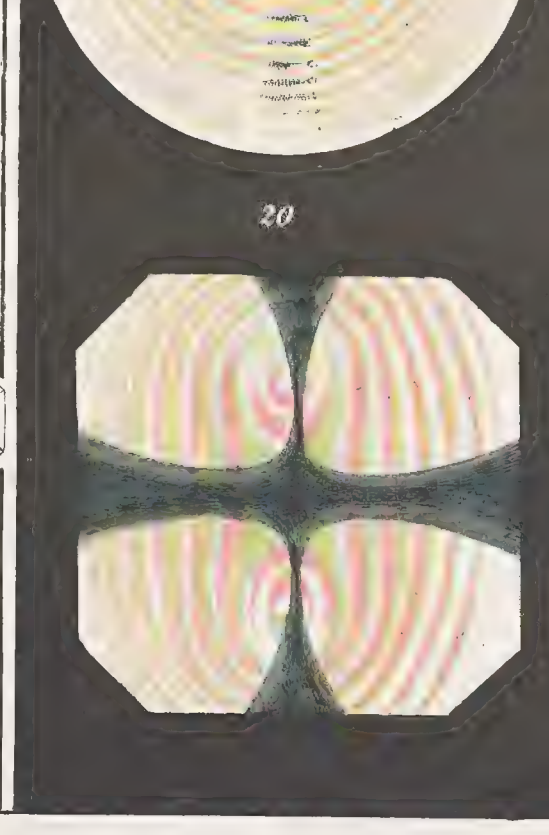

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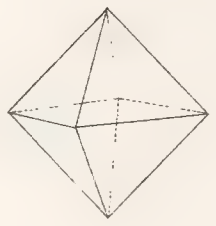

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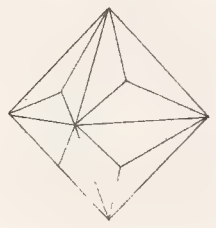

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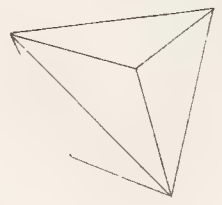

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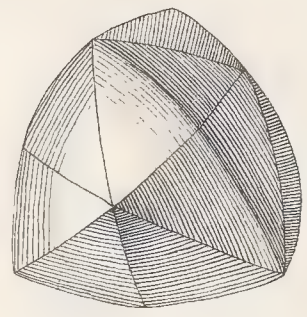

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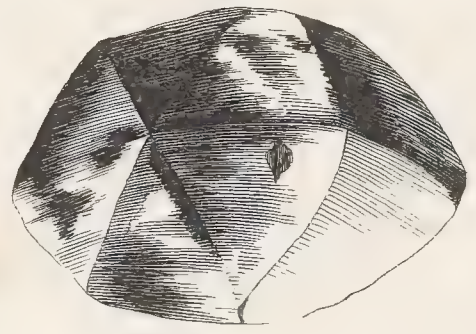

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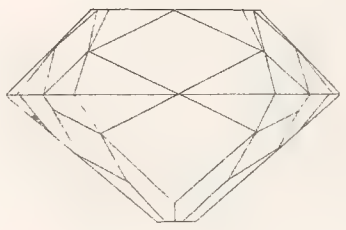

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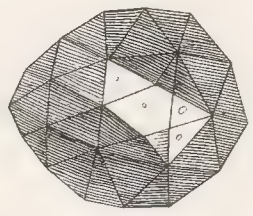

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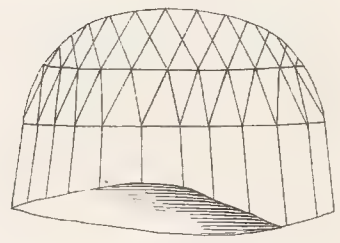

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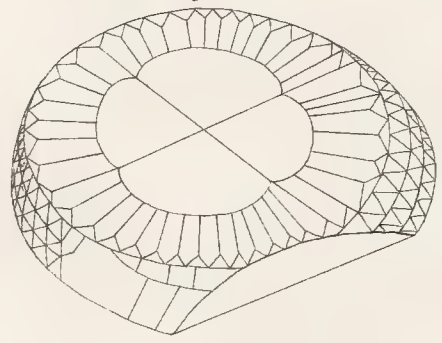

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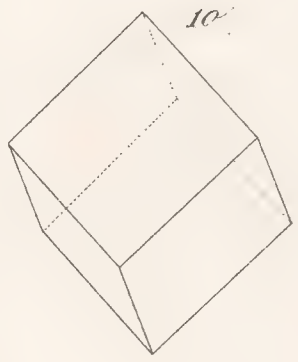

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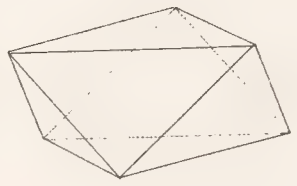

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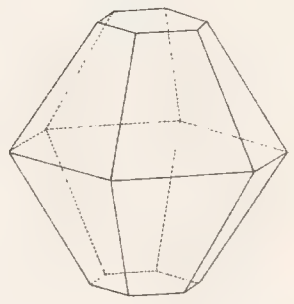

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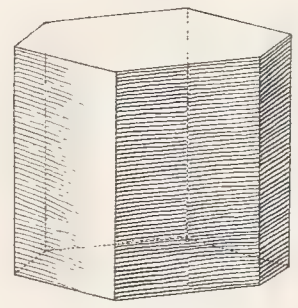

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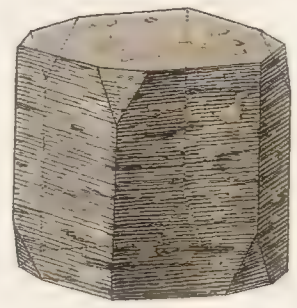

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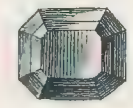

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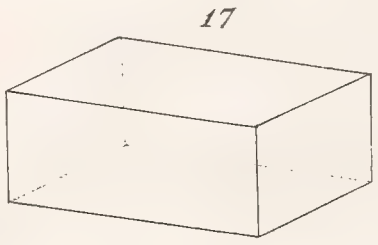

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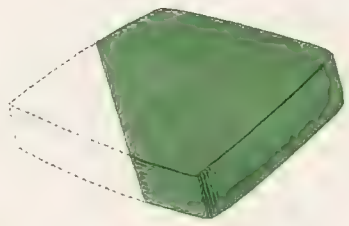

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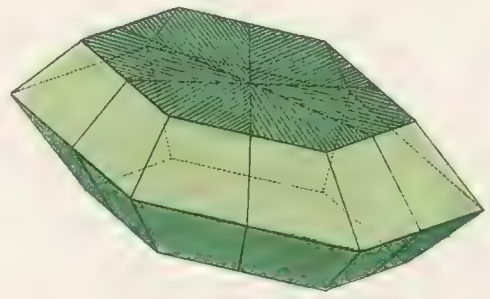

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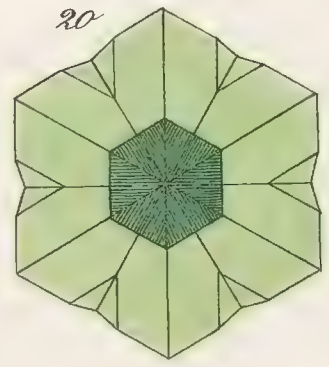

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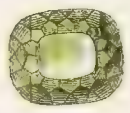

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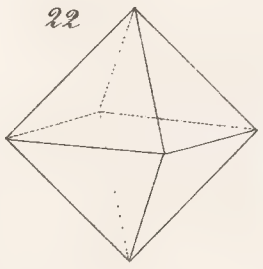

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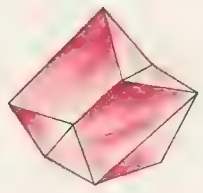

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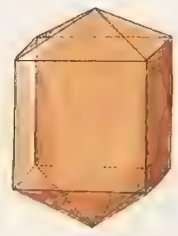

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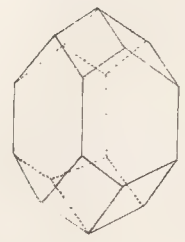

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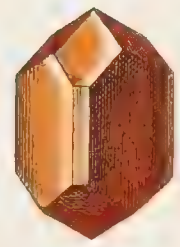

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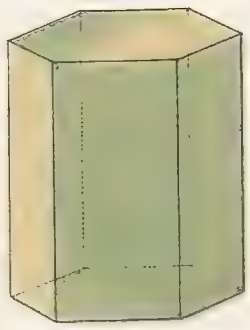

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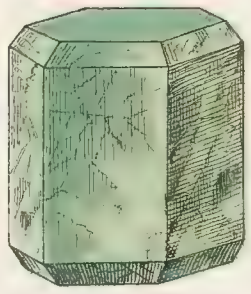

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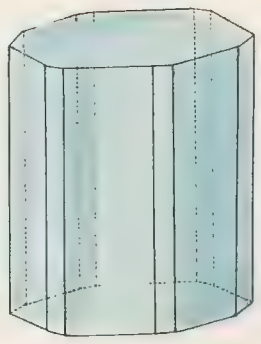

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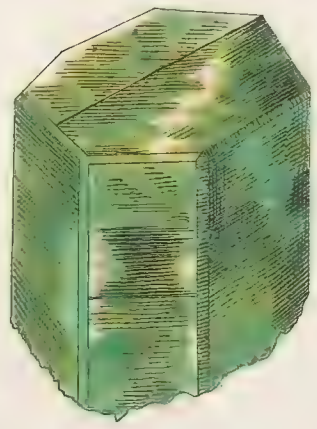

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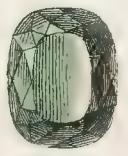

PLATE I.

Figs. 1—9.—The Diamond.

1. This figure represents the primary form of the *diamond*—a *simple regular Octahedron.* A stone of this size was shown in the Paris Exhibition of 1855; the colour was of a yellowish white, perfectly clear and transparent. The planes were, however, somewhat curved.

2. *The pyramidal Octahedron*, the most usual form of the Brazilian diamonds. The planes are also, for the most part, somewhat curved.

3. *The pyramidal Tetrahedron*, likewise occurring in Brazilian diamonds, especially in twin crystals.

4. The *double pyramidal Tetrahedron*, or *six-faced tetrahedron* (*icositetrahedron*), the half of the forty-eight-faced solid, with curved and striated faces, also found in Brazilian diamonds.

5. *The Star of the South* (*Etoile du Sud*), natural size, as it was found in 1852 in the mines of Bagagem, in the province of Minas Geraes, in Brazil. Shown in Paris in the Industrial Exhibition of 1855. It is almost as clear as water, slightly tinged with yellow. It weighs 254 carats, and is valued at two and a half millions of francs (nearly £100,000). It is 30 millimetres in height, 40 in length, and 27 in breadth. Its shape is a twelve-faced rhomboid, presenting altogether twenty-four triangles. The faces are somewhat dull, and have octahedral streakings. It would probably lose half of its weight if it were cut, and would then take the fifth place among known diamonds.

6. *The Regent*, or *Pitt diamond*, in possession of the French crown. When rough, it weighed 410 carats, and now, when cut as a brilliant, its weight is 136 carats. It was bought by the Duke of Orleans for two and a half millions of francs (£98,958), from the celebrated statesman whose name it bears, and is now valued at £125,000. It is perfectly pure and transparent, and sparkles with a magnificent play of colour. It is undoubtedly the most beautiful of all known diamonds. Like all those which follow, it is from the East Indies.

7. *The Saucy*, in possession of the Emperor of Russia, who bought it for half a million of francs (about £20,000). It has the form of a somewhat irregular pyramidal dodecahedron, is perfectly transparent, and weighs $53\frac{1}{2}$ carats.

8. The diamond on the top of the Russian sceptre. It has the form of the knob of a cane; its weight is 195 carats, and it is worth 450,000 rubles, or 1,800,000 francs (about £70,000). The under surface is a plane. Another of the Russian crown diamonds weighs as much as 779 carats, and is valued at 34,000,000 of thalers, or nearly £5,000,000.

9. The *Koh-i-noor*, or *Mountain of Light*, formerly in possession of the Great Mogul of Delhi, now the property of Her Majesty Queen Victoria. At one time it weighed 280 carats, and then had the form of the figure in the plate. It was afterwards repolished, and thereby lost weight. It is valued at about £600,000.

The diamond of the Portuguese crown, however, of the form and size of a duck's egg, is the largest known specimen, for it weighs 1680 carats, and must therefore be worth 1568 millions of thalers (£227,033,333 ! !)

These prices are all calculated according to a fixed rule said to regulate the price of diamonds. Mr. M'Culloch has, however, in his Commercia, Dictionary, pointed out the fact that "the value of the largest diamonds can depend upon nothing but the competition of the purchasers.' He adds, that "the famous diamond belonging to the Emperor of Russia, which the jewellers tell us is worth £4,804,000, did not cost £150,000.',

Figs. 10—16.—Corundum, or Corundite (Sapphire and Ruby).

10. Represents the primary form, *an ordinary rhombohedron.*

11. *The same*, with truncated extremities.

12. *The six-sided double pyramid*, as it occurs in the yellowish white translucent corundum of India.

13. The *common Corundum*, in hexagonal prisms, from Mysore in the East Indies.

14. *The same*, with truncation of alternate solid angles, the combination of the prism with the rhombohedron—both distinctly striated horizontally.

15. *The Ruby*, or *precious red Corundum*, one of the most valuable of precious stones.

16. The *Sapphire*, or *blue Corundum*, from the East Indies.

Figs. 17—21.—Chrysoberyl.

17. *Right rhomboidal prism*, primary form of chrysoberyl.

18. *The same*, with truncation of a lateral edge. From Haddam, United States.

19. A crystal composed of six twins grouped together laterally, which, in transmitted light, appears red. From Siberia.

20. *The same*, in a horizontal section.

21. A tabular *polished Chrysoberyl.* From the East.

Figs. 22, 23.—Spinel.

22. *Spinel*, primary form—a regular octahedron.

23. *Spinel*, rose-red, occasionally ruby-red—two half octahedrons united as twins. From Ceylon.

Figs. 24—27.—Zircon—Hyacinth.

24. *Brown Zircon*, a square prism in combination with the square octahedron. From Fredericksvärn, Norway.

25. *The same*, a square prism with a quadratic octahedron at the solid angles, the most usual form of brown hyacinth. From Ceylon.

26. *The same*, with truncation of the lateral edges; square octahedron, with octagonal prism. From the Ilmen Mountains.

27. *Hyacinth*, from Ceylon; cut as a stone for a ring.

Figs. 28—33.—Beryl and Emerald.

28. *Beryl*, primary form; a simple six-sided prism. From Bodenmais, in Bavaria.

29. *Beryl*, six-sided prism, with truncation of the basal edges. From Greenland.

30. *Sea-green Beryl*, known as *aqua-marine*; six-sided prism, with truncation of the lateral edges. From the Ilmen-gebirge.

31. *Emerald*, dark green, six-sided prism, with truncation of the basal and lateral edges; twins; half the size of a crystal; in the cabinet of the Duke of Devonshire. From Muzo, north of Santa Fé de Bogota, in Granada. It weighs 8 oz. 18 dwts.

32. *Emerald*, cut for a ring. From the emerald mines of Egypt.

33. *Beryl*, cut as a stone for a ring. From Siberia.

PLATE II.

Figs. 1—7.—The Topaz.

1. *Topaz*, primary form, right rhombic prism.
2. *The same*, vinous yellow, with simple truncation of the acute angles and basal edges, and double truncation of the acute lateral edges, the most usual form of the Saxony crystal, from Schneckenstein near Auerbach in Vogtland.
3. *Dark yellow Topaz*, a rhombic prism, with sharpening of the acute lateral edges, and simple truncation of the basal edges (rhombic octahedron), from Brazil.
4. *Sea-green Topaz or Aqua-marine*, with simple truncation of the lateral and basal edges, and double truncation of the acute angles, from Mursinsk near Katherinenberg.
5. *Light yellow Topaz*, cut for a brooch stone, from Brazil.
6. *Dark yellow Topaz*, cut as a stone for a ring, from Brazil.
7. *The same*, heated and rose-red, the so-called balais, from Brazil.

Figs. 8—19.—The Garnet.

8. *Common Garnet*, brownish red, primary form a rhombic dodecahedron, from the Tyrol.
9. *Primary form* of the garnet, with truncation of all the edges, combination of this and the trapezohedron or leucitoid.
10. *Trapezohedron*, as it occurs in the Bohemian garnet, pyrope, and in grossular.
11. *Rhombic dodecahedron*, with double truncation of the edges, union of the leucitoid and forty-eight faced solid, as it occurs in the common garnet of Auerbach and North America.
12. *Lime-chrome-Garnet* or *Ouvarovite*, primary form in chromic ironstone, from, Bissersk in Siberia.
13. *Noble Garnet* or *Pyrope*, cut as a stone for a ring, from Bohemia.
14. *Noble Oriental Garnet*, cut as a stone for a pin, from Ceylon.
15. *Red Noble Garnet*, cut as a stone for a brooch, from the Tyrol.
16. *Noble Garnet* or *Topazolite*, rhombic dodecahedron, from Brazil.
17. *Green Garnet* or *Grossular*, from Siberia.
18. *Black Garnet* or *Melanite*, primary form with truncation of the edges, from Frascati near Rome.
19. *Ruby Garnet*, cut as a stone for a ring, from Ceylon.

Figs. 20—24.—Vesuvian and Idocrase.

20. *Vesuvian*, primary form a quadratic prism, with truncation of the lateral edges.
21. *The same*, with truncation of the lateral and basal edges, olive green, from Siberia.
22. *The same*, dark green, with truncation of basal angles and lateral edges, from Piedmont.
23. *Brown Vesuvian*, imbedded in stone, with truncation of the lateral and basal edges, from Vesuvius.
24. *Cut Vesuvian*, grass-green, from Piedmont.

Figs. 25—27.—Chrysolite, Olivine.

25. *Chrysolite*, right rectangular prism, primary form.
26. *The same*, with truncation of the long basal and of the lateral edges.
27. *The same*, cut as a stone for a ring, from the East.

Figs. 28—30.—Pistacite, Epidote.

28. *Pistacite*, primary form a right rhomboidal prism.
29. *The same*, with truncation of the lateral and basal edges, in reddish calcite, from Arendal in South Norway.
30. *The same*, with truncation of the acute angles and lateral edges.

Figs. 31—34.—Turquoise, Johnite, Calaite.

31. *Grape Johnite*, in a yellowish mass of quartz, from Silesia.
32. *Apple-green Turquoise*, in gray calcareous marl, from Thibet.
33. *The same*, cut, from the same locality.
34. *Bluish-green Turquoise*, cut as a table, also from Thibet.

Figs. 35 and 36.—Lazulite, Lapis Lazuli.

35. *Light-blue Lazulite*, mingled withwhite quartz, from Sliudanka in Siberia.
36. *Dark-blue Lapis Lazuli*, with pyrites dispersed over it, from Belur-Tag, at Orus in Tartary, cut as a trinket.

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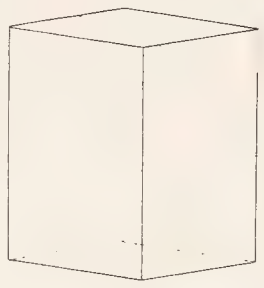

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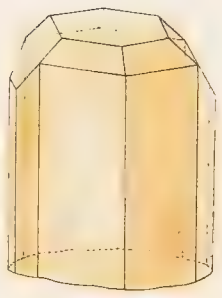

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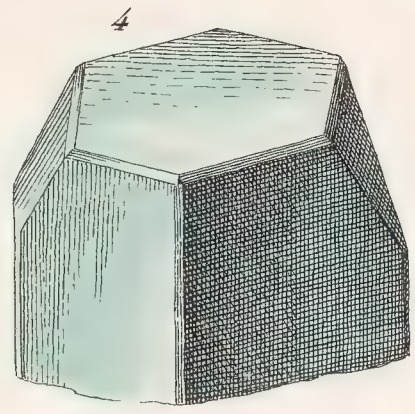

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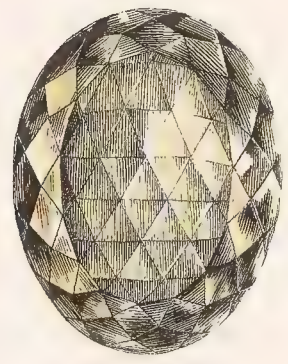

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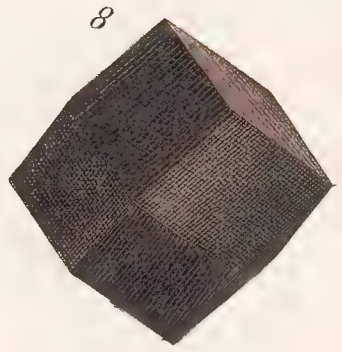

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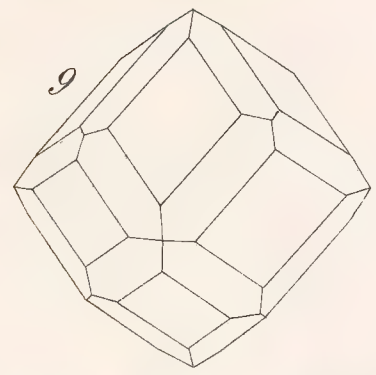

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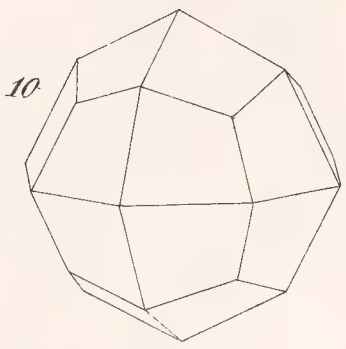

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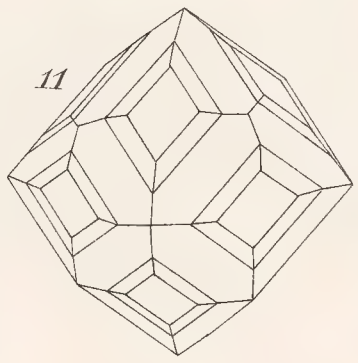

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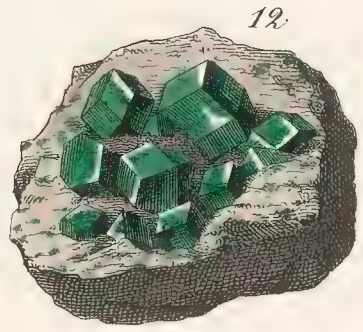

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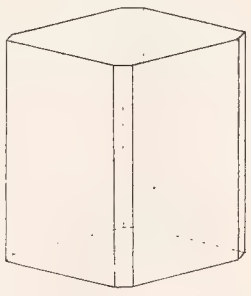

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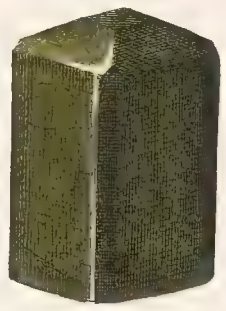

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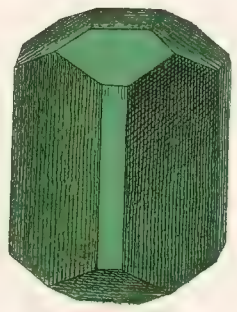

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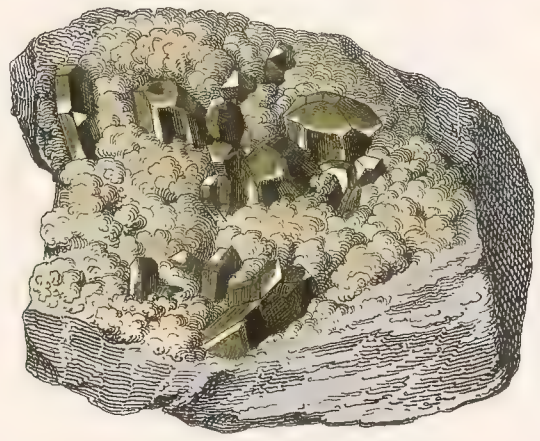

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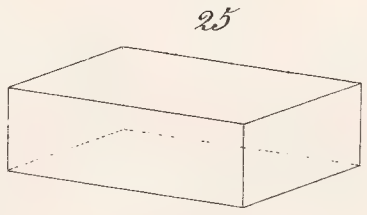

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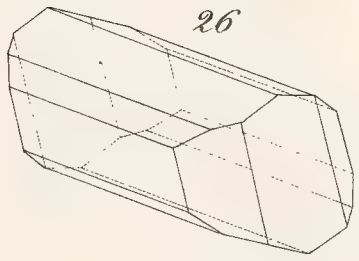

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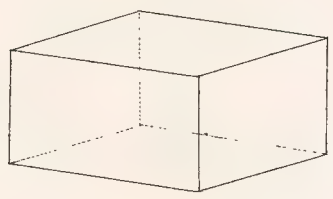

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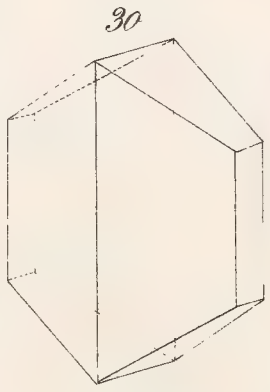

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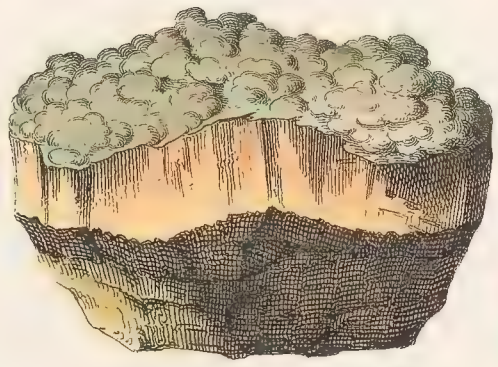

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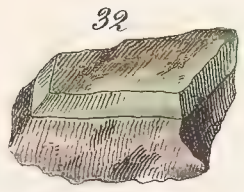

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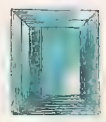

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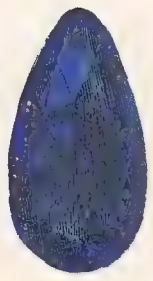

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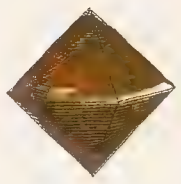

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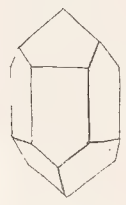

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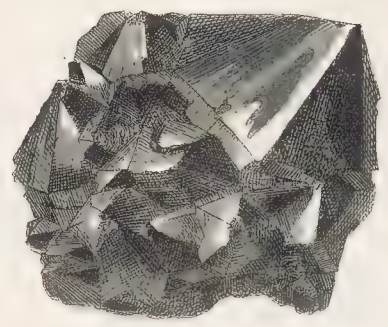

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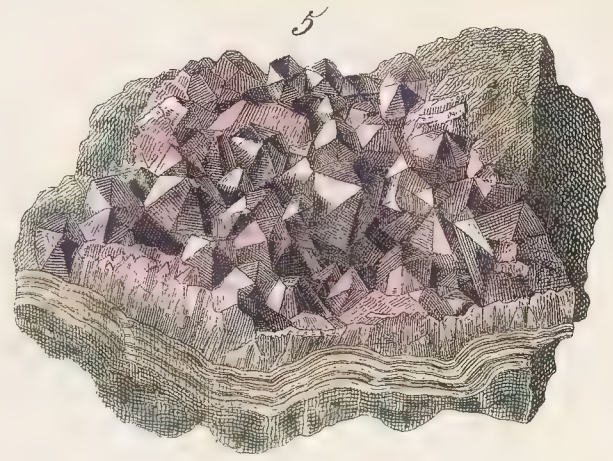

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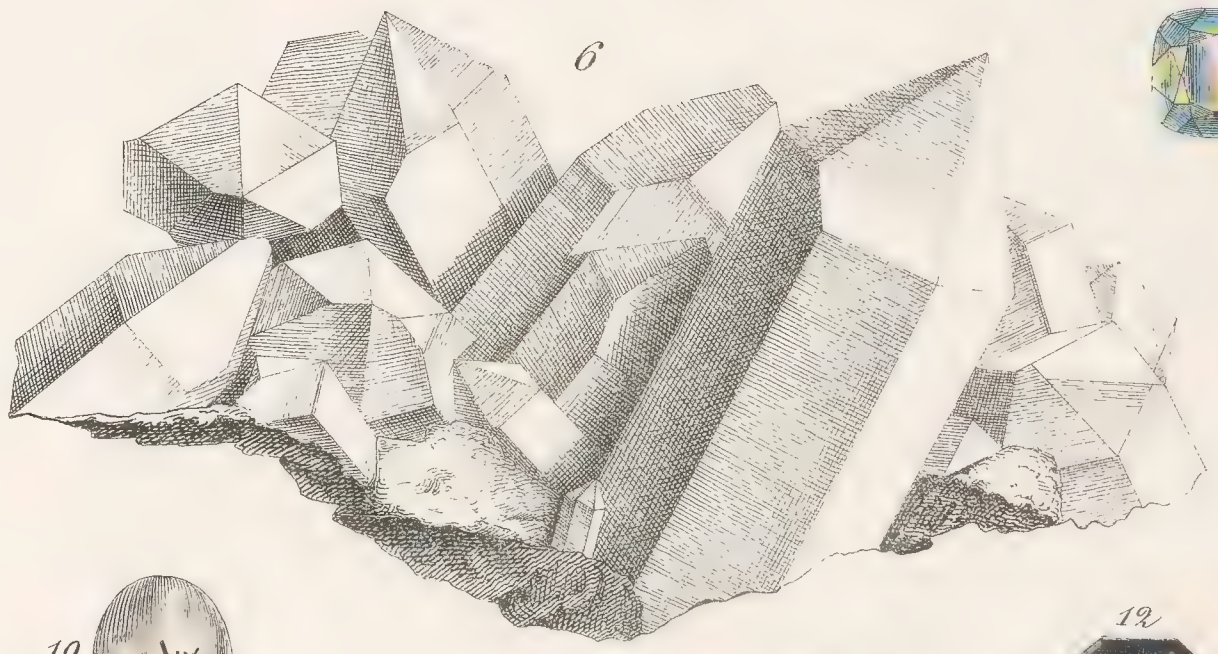

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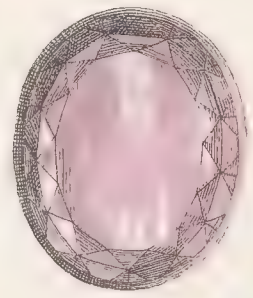

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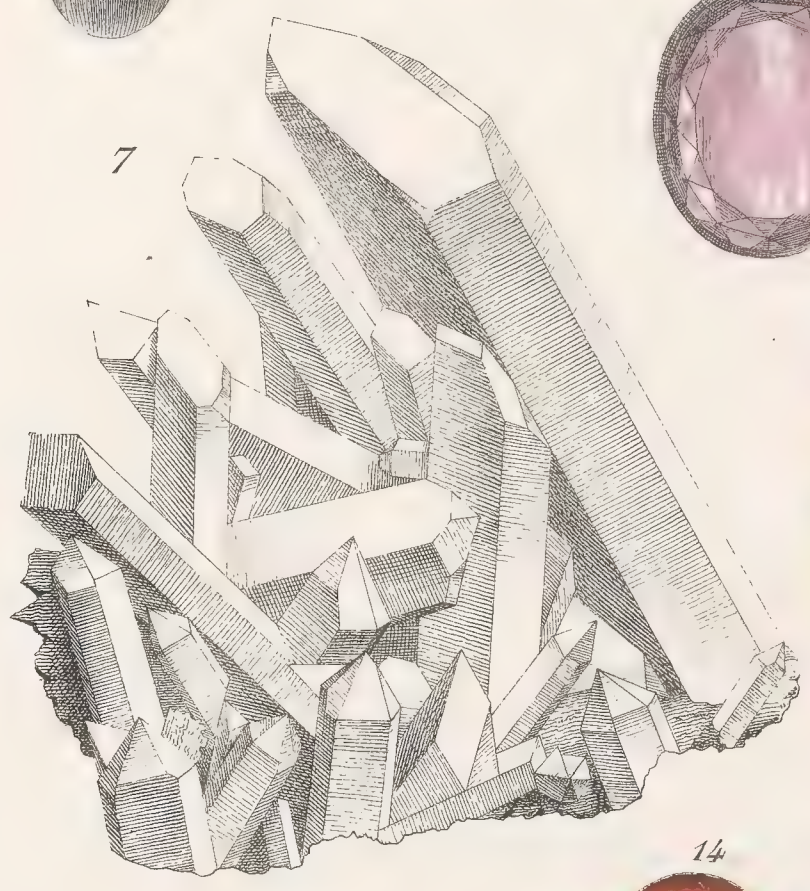

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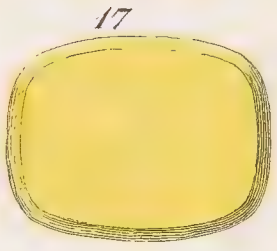

PLATE III.

Figs. 1—19.—Quartz.

1. Yellowish-red *Ferruginous Quartz*, crystallised as a double hexagonal twin pyramid, from Compostella in Spain.
2. *Rock-crystal*, a rhombohedron, with the hexagonal prism, resulting from truncation of the basal angles, from Amsteg, at the Gotthardtstrasse.
3. *Rose Quartz*, double pyramid and hexagonal prism, all the faces regularly shaped, from the East Indies.
4. *Smoky Quartz*, in hexagonal pyramids, from the copper gangs of the variegated sandstone at Neubulack in the Black Forest of Wirtemberg (*Schwarzwald*).
5. *Amethyst*, in six-sided pyramids, in a mass of agate, from Chemnitz in Hungary.
6. Group of *Rock crystal*, in hexagonal prisms and pyramids, transparent, from a crystal cavern at Gotthardt.
7. Group of *Rock crystal*, with a predominance of solitary crystals, part of them truncated at basal angles, transparent, with a yellowish shade, from Dauphiné.
8. *Amethyst*, cut as a stone for a brooch, from Brazil.
9. Nodule of *Egyptian Jasper*, striped with brown.
10. Nodule of *Jasper* polished, red and yellow, from Auggen in Upper Baden.
11. *Ribbon Jasper*, striated with red and green, from Siberia.
12. *Heliotrope*, or *blood-stone*, dark green and dotted with red, polished as a stone for a ring, from the East.
13. *Heliotrope*, polished, from the Southern Tyrol.
14. *Light red Carnelian*, from Egypt, cut for a ring.
15. *Moss Agate*, or *Mocca-stone*, white chalcedony, with dendrites, or moss-like figures, from the East.
16. Yellow and white polished *Chalcedony*.
17. Light yellow *Chalcedony*, polished.
18. *Milky Quartz*, with brilliant play of colours, cut as a stone for a ring.
19. *Needle Amethyst*, a pale amethyst, with small enclosed crystals of tourmaline, from New Holland.

PLATE IV.

FIGS. 1—20.—QUARTZ AND OPAL.

1. *Grey and white striped Flint*, fragment of a large mass, from Kandern in Baden.
2. *Carnelian*, fragment of a roundish mass, from Egypt.
3. *Fortification Agate*, as it is used for vases, polished in a transverse section, from Oberstein.
4. *Clouded Agate*, brown, red, and white, from Oberstein.
5. *Puddingstone*, or *Quartz Conglomerate*, from Scotland.
6. *Vitrified tube*, a fragment from the Swiss heaths.
7. *Wood Opal*, a petrified pine, from Hungary.
8. *Chrysoprase*, polished, from Silesia.
9. *Black and White marked Agate*, cut.
10. *Black ribbon Agate*, Arabian Onyx, from the East.
11. *Dark brown ribbon Agate*, from the East.
12. *Horny-coloured Agate*, from the East Indies.
13. *Sardonyx*, or *Sard*, from the East.
14. *Onyx*, light brown and black, from the East.
15. *Red dotted Agate*, from Saxony.
16. *Brecciated Agate*, from Saxony.
17. *Red striped Agate*, from Saxony.
18. *Variegated Striped Agate*, from Saxony.
19. *Precious Opal*, from Czerwenitza, in Hungary.
20. *Green Opal*, from Pernstein in Moravia.

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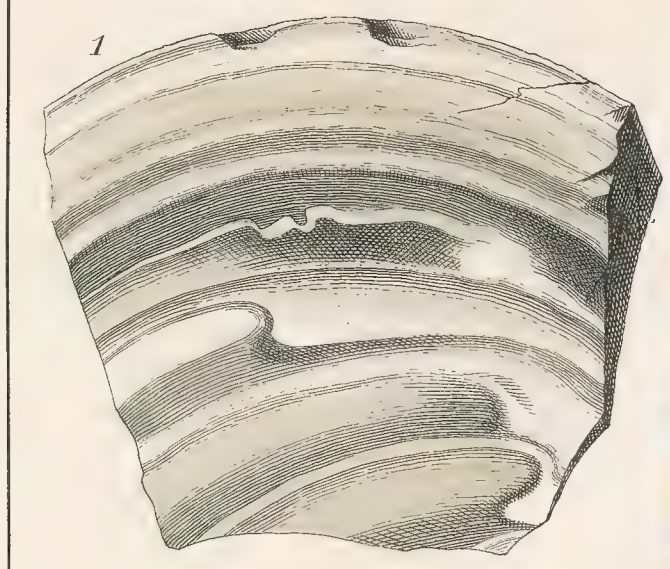
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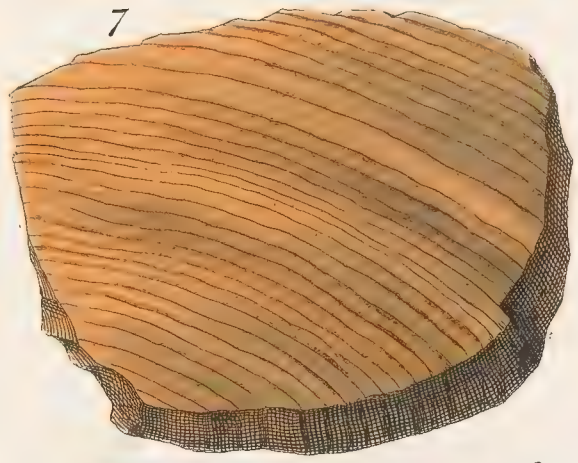
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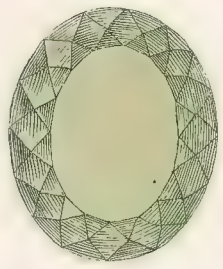
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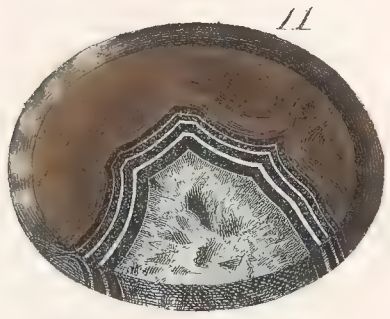
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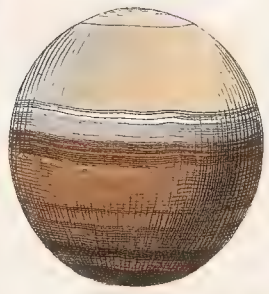
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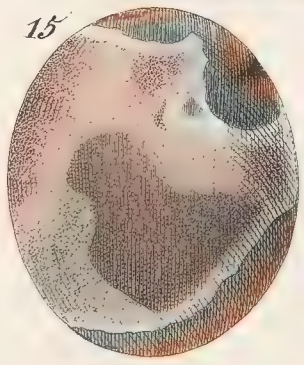
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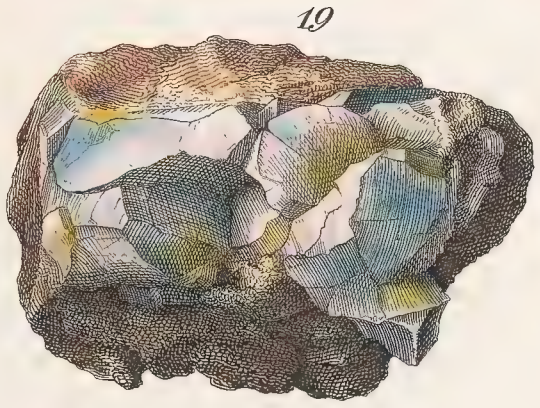
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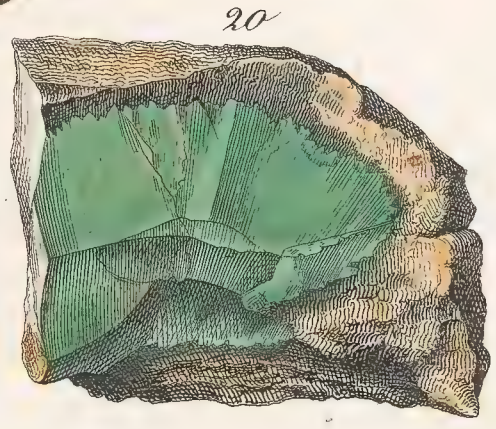
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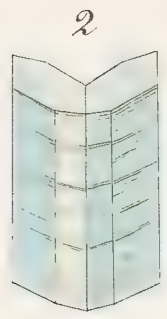
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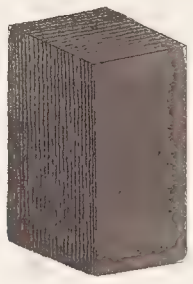
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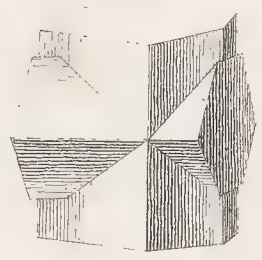
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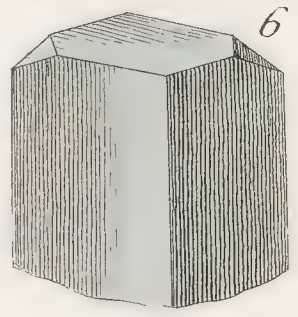
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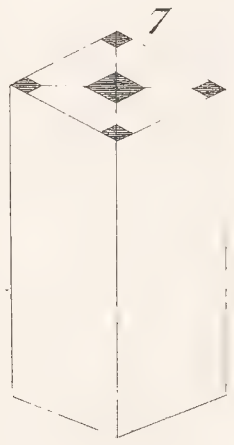
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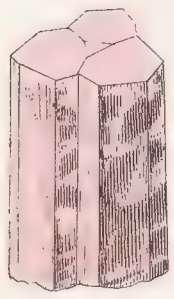
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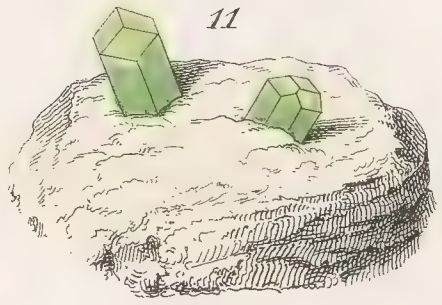
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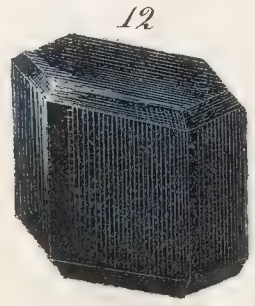
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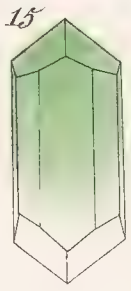
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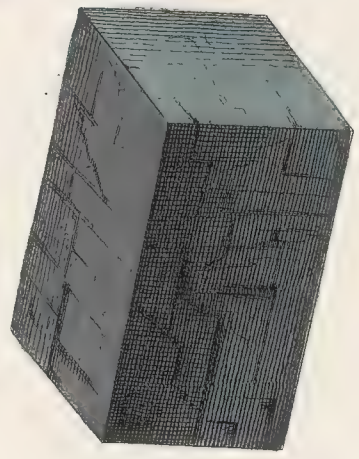
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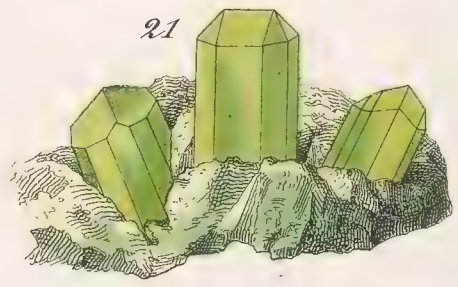
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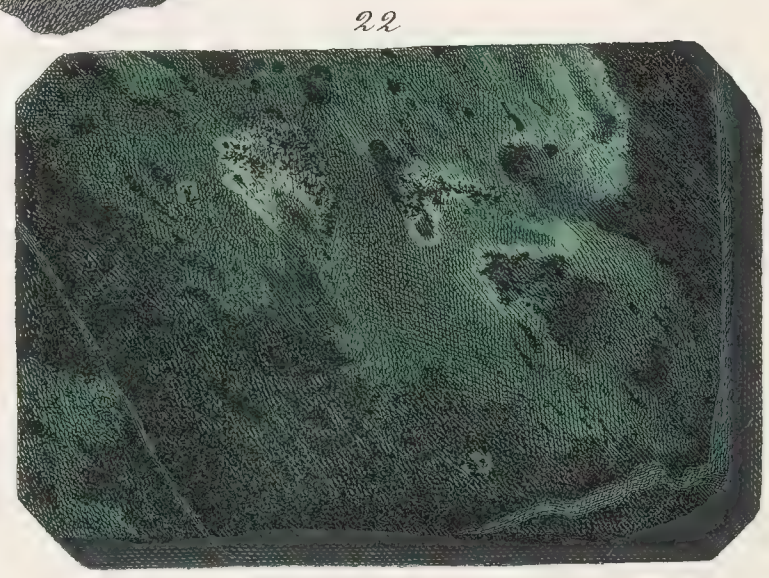
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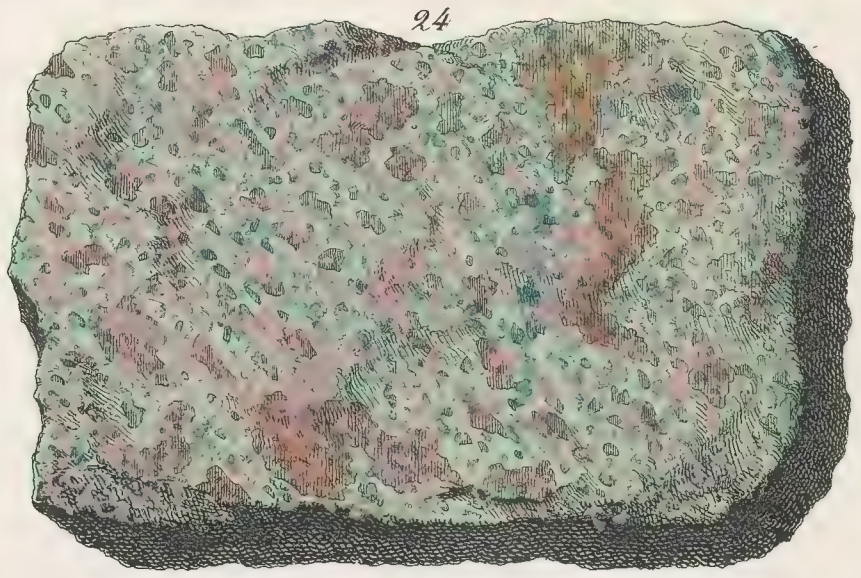
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PLATE V.

Figs. 1 and 2.—Kyanite, Disthene.

1. *Kyanite*, light blue, oblique rhombic prism, with truncation of the lateral edges, from St. Gothard.
2. *The same*, two crystals joined as twins, oblique rhombic prism, with truncation of the obtuse lateral edges.

Figs. 3—5.—Staurolite.

3. *Staurolite*, reddish brown, primary form a right rhombic prism, from Dauphiné.
4. *The same*, with truncation of the acute lateral edges and of the obtuse angles, two half crystals united twin-wise in the direction of the long axis, from St. Gothard.
5. *The same*, with truncation of the acute lateral edges, twins, in the form of a cross.

Figs. 6 and 7.—Andalusite.

6. *Andalusite*, primary form a right rhombic prism, with truncation of the acute angles, pearl-grey, from Sisens in the Tyrol.
7. *Hollow-Spar* or *Chiastolite*, four segments of crystals united vertically; the intervening spaces are filled up with clay-slate, from St. Jago di Compostella in Spain.

Figs. 8—11.—Tourmaline.

8. *Brown vertically striated Tourmaline*, a nine-sided prism, with three sharpened rhombohedral planes, from the Zillerthal in the Tyrol.
9. *The same*, dark brown, with three rhombohedral planes at the extremity, which make the nine-sided prism pointed, from Modum in Norway.
10. *Rose-red Noble Tourmaline*, or *rubellite*, three crystals aggregated as a triplet, with straight truncation of the apex, so that the rhombohedral planes have disappeared; each crystal forms a six-sided prism, from Slatousk in the Urals.
11. *Green Precious Tourmaline*, in yellowish dolomite; the crystal to the left presents three rhombic terminal planes (the primary form being a rhombohedron), and six rhomboidal lateral planes, arising from the truncation of the basal edges (of the hexagonal prism). The other crystal on the right presents the rhombohedron with truncation of the vertex, and united to the nine-sided prism. From Campo Longo on the south side of St. Gothard.

Figs. 12 and 13.—Dichorite, Peliom, or Iolite.

12. *Peliom*, primary form a right rhombic prism, with truncation of the acute lateral edges and all the basal edges, dark blue, from Bodenmais in Bavaria.
13. *The same*, light blue, with play of white, the so-called *lynx-sapphire*, cut as a stone for a ring, from Ceylon.

Figs. 14 and 15.—Augite.

14. *Common Augite*, dark brown, an oblique rhombic prism, with truncation of the acute angles and of the obtuse lateral edges, from Frascati near Rome.
15. *Green Augite, diopside or baikalite*, green and white, an oblique rhombic prism, with truncation of all the lateral and basal edges, from Piedmont.

Figs. 16—18.—Hornblende, Amphibole.

16. *Dark-green Hornblende*, or *Actinolite*, primary form an oblique rhombic prism, from Greiner in the Tyrol.
17. *Black or Basaltic Hornblende*, an oblique rhombic prism, with truncation of the acute lateral and acute basal edges, from Bohemia.
18. *Long-fibrous Hornblende, green asbestus*, from Pfitsch in the Tyrol.

Fig. 19.—Hypersthene.

19. *Paulite or Hypersthène*, copper-red inclining to blackish, with distinct structure in oblique rhombic plates, a fragment, from the island of St. Paul's.

Fig. 20.—Mountain Wood.

20. *Mountain Wood*, or *Wood Asbestus*, fibrous, yellowish-brown, differs from common asbestus by containing water, from Sterzing in the Tyrol.

Figs. 21—23.—Serpentine, Ophite.

21. *Noble Serpentine*, greenish yellow, in right rectangular prisms, with truncation of the lateral edges and of the basal angles and edges, from Snarum in Norway.
22. *Dark-green Serpentine*, streaked and mottled, polished as the lid of a box, from the Apennines.
23. *White Mottled Serpentine*, a mixture of serpentine, talc, and chalk, so-called *green marble*, *Ophicalite* or *Verde de Corsica duro*, from Corsica.

Fig. 24.—Omphacite.

24. *Schiller-Spar*, *diallagite* or *smaragdite*, in granular mixture with common granite, from Gefrees in the Fichtelgebirge.

PLATE VI.

Figs. 1—10.—Felspathic Minerals and Rocks.

1. *Potash Felspar*, primary form, the oblique rhombic prism, as it sometimes occurs at Adula in the Zillerthal, and at St. Gothard.

2. *Apple-green Felspar*, or *Amazon Stone*, oblique rhombic prism, with truncation of the acute angles, and double truncation of the obtuse lateral edges, from the Urals.

3. *Common Felspar*, or *Orthoclase*, primary form, a horizontal prism, with truncation of all the edges and angles, from the Fichtel Mountains.

4. *Adularia*, four twins united in the form of a cross, each crystal with truncation of the obtuse angles, from St. Gothard.

5. *Sodalite*, *Albite*, *Pericline*, an oblique rhomboidal prism, with truncation of the obtuse lateral and basal edges, and of an acute angle, as it occurs in the Zillerthal.

6. *Green Porphyry Felspar;* the primary mass of compact felspar, coloured green by hornblende, contains crystals of light-green felspar embedded in it, from Greece, The green porphyry of the ancients.

7. *Black Porphyry*, mottled with white, otherwise of a composition similar to that of the last, from Elfdal in Sweden.

8. *Red Antique Porphyry*, of the same composition, but of a reddish-brown colour, from the quarries of Syene in Upper Egypt, frequently used by the ancient Egyptians in the construction of monumental work.

9. *Labrador Felspar*, with play of blue and green, polished; the small rhomboidal planes of cleavage are distinctly seen, from Labrador.

10. *The same*, with play of colours from red to yellow, and from green to blue, polished, from the same locality.

Figs. 11—15.—Micaceous Minerals.

11. *Pennine*, or *Talcose Mica*, an acute rhombohedron, with truncation of the vertex, from Zermatt in Wallis, usually dark green.

12. *Common*, or *Bi-axial Mica*, oblique rhombic lamellar aggregations, silver-white, from the granite of Modum in Norway.

13. *Black Potash Mica*, six-sided table, from Vesuvius.

14. *Ripidolite*, or *Prismatic Chlorite*, a double hexagonal pyramid, with right terminal planes, dark green, from Pfitsch in the Tyrol.

15. *Talc*, in curved rhombic prisms, with truncation of the acute lateral edges, twisted together in the form of a worm, made up of thin laminæ, from Piedmont.

Figs. 16 and 17.—Granite.

16. *Granite*, of a medium grain, composed of reddish and white felspar, grey quartz, and black mica, polished from Baveno near Mailand.

17. *Red Granite*, coarsely granular, consisting of red felspar, grey quartz, and black mica, from the quarries of Syene in Upper Egypt, frequently used by the ancient Egyptians in their monuments and more important buildings.

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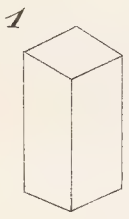

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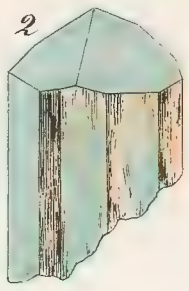

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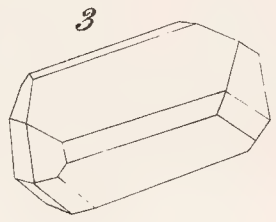

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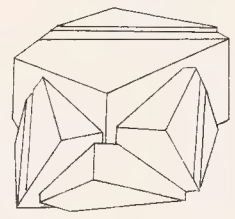

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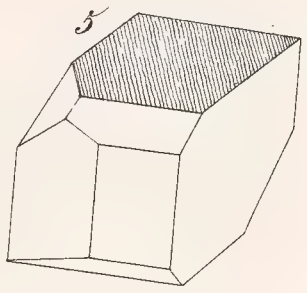

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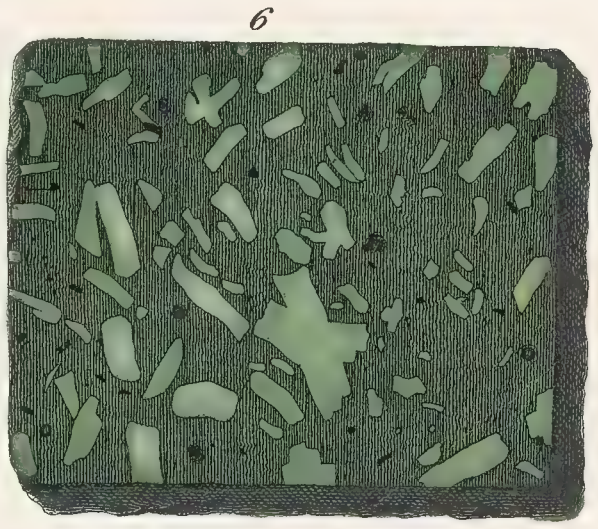

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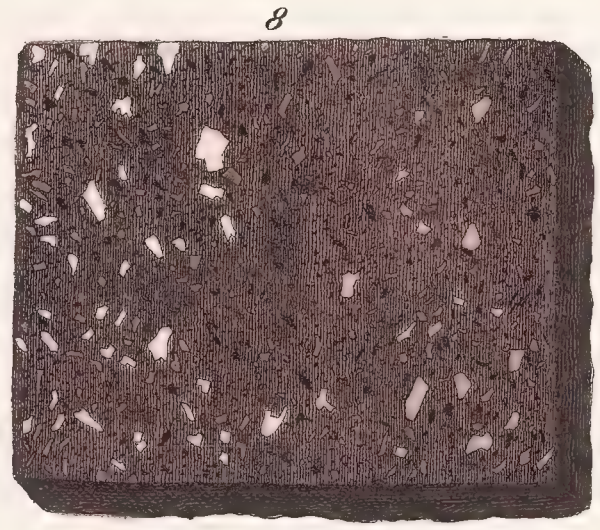

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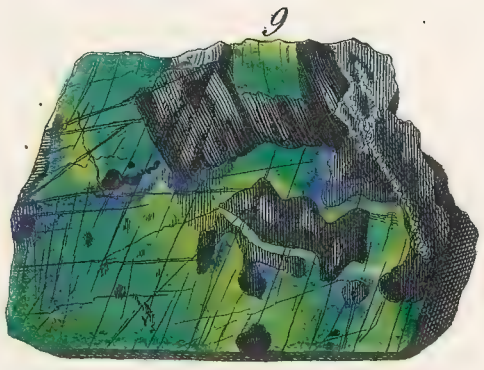

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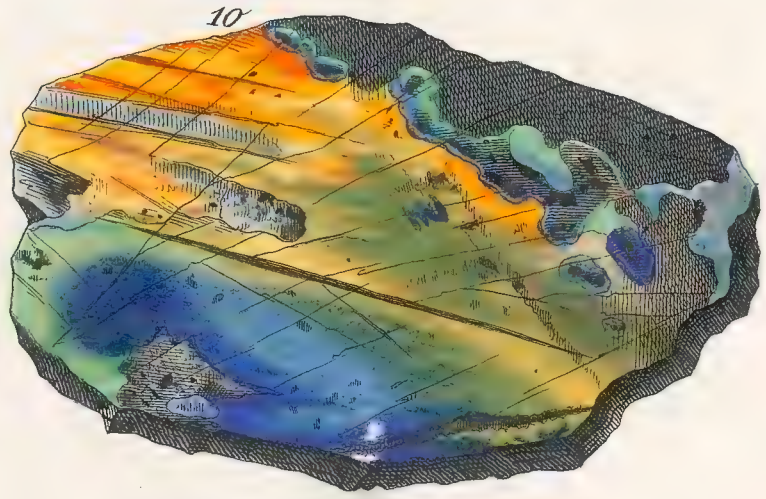

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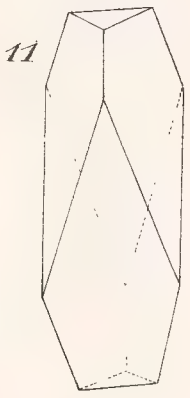

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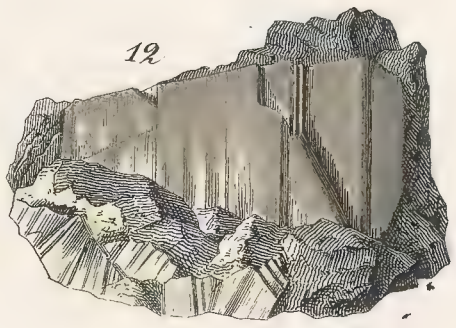

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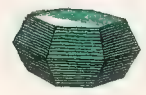

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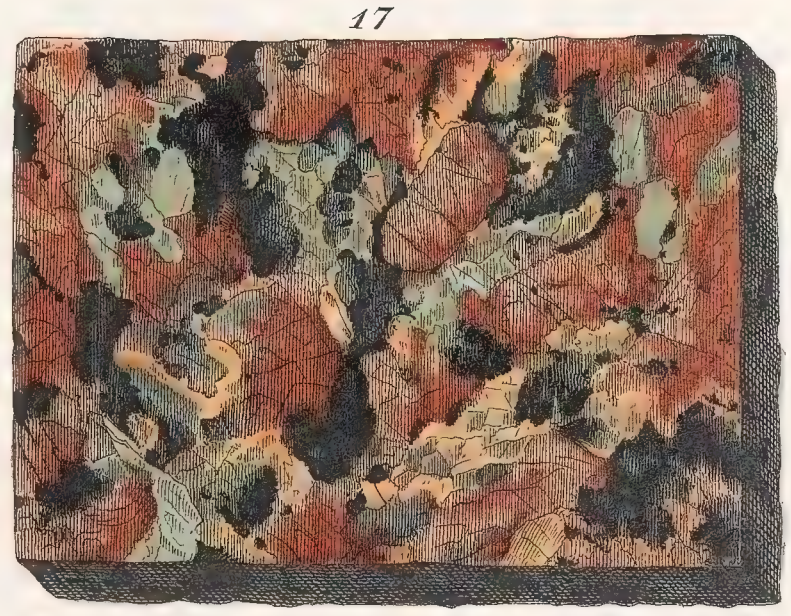

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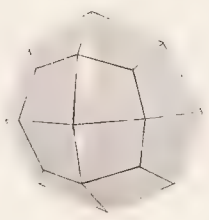

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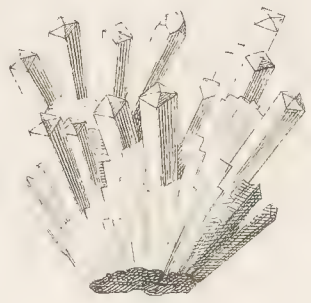

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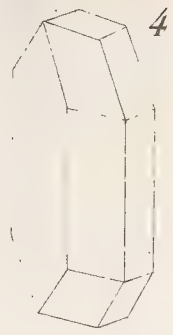

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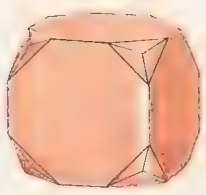

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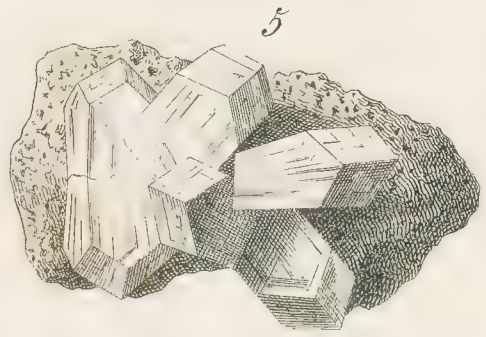

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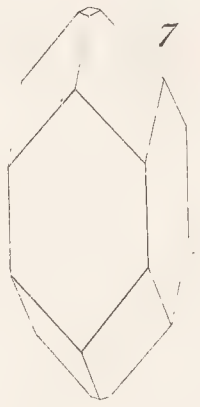

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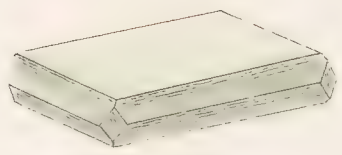

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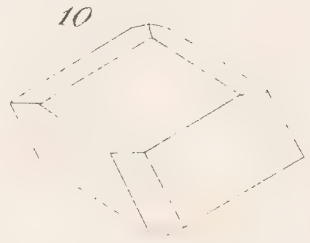

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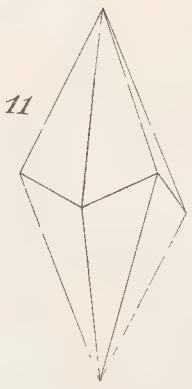

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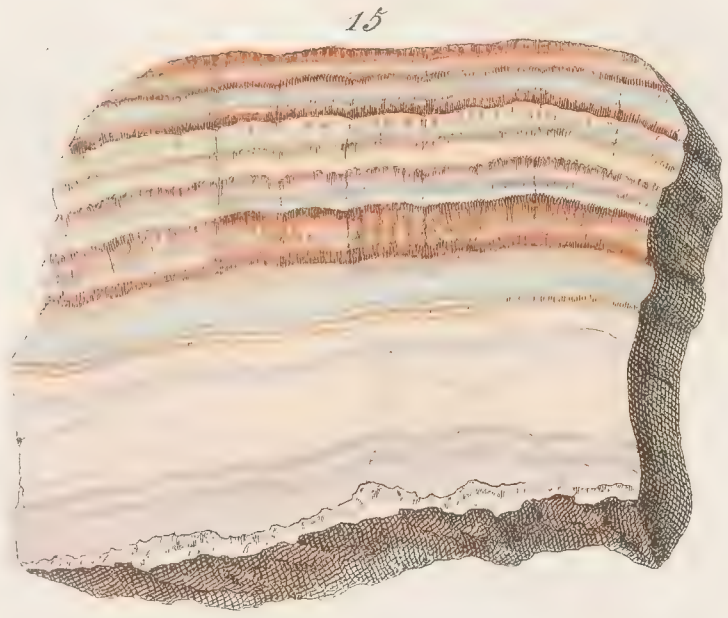

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PLATE VII.

Figs. 1—8.—Zeolitic Minerals.

1. *Leucite*, crystallised as a trapezohedron, which is for this reason also called a *leucitoid*. Pearl-grey, from the ancient lava of Vesuvius.

2. *Natrolite*, radiated, with concentric rings, and marked yellow, red, and white, on clinkstone, in splinters of phonolite, from Hohentwiel in Swabia.

3. *Crystallised Zeolite*, or *Mesotype*, right rhombic prism, with four bevelled planes (rhombic octahedron), colourless and transparent, from Auvergne.

4. *Heulandite*, oblique rhombic prism, with truncation of the acute lateral, and basal edges.

5. *Stilbite*, or *Foliated Zeolite*, right rectangular prisms, with truncation of the basal angles (rhombic octahedron) in wedge-shaped aggregations of lamellæ, from the amygdaloid of the Faröe Islands.

6. *Analcime*, primary form, a cube with triple truncation of the acute angles (leucitoid), from the amygdaloid of the Alps in the South Tyrol.

7. *Apophyllite*, quadratic prism, the primary form, with truncation of the angles (square octahedron), as it occurs at Andreasberg in the Harz Mountains of a rose-red colour, and at the Faröes colourless.

8. *The same*, of a tabular form, combination of the quadratic octahedron with the lower quadratic prism, the so-called *ichthyophthalmite*, or fishes-eyes-stone, from the Fassathal in the South Tyrol.

Figs. 9—18.—Carbonaceous Limestone.

9. *Calcareous Spar*, or *calcite*, primary form, a hexagonal rhombohedron, a fragment of double refracting Icelandic spar.

10. *The same*, with truncation of the vertical edges, combination of the intermediate with the obtuse rhombohedron, from Münsterthal in Baden.

11. *The same*, a hexagonal double pyramid, with unlike edges, scalenohedron, from a splinter of the mussel-chalk at Canstatt.

12. *Calcareous Spar*, acute rhombohedron, as it frequently occurs in veins at the Schwarzwald and Erzgebirge in Saxony, and mingled with fine quartz sand at Fontainebleau (the so-called sandstone crystals of Fontainebleau).

13. *The same*, secondary rhombohedron, with truncation of all the basal angles (hexagonal prism), from Andreasberg in the Harz Mountains.

14. *The same*, a six-sided double pyramid, twins, with dissimilar edges, united horizontally, from Canstatt.

15. *Fibrous Calcite*, *dragonite*, streaked red, yellow, and white, and polished, the so-called thermal *tufa* (*Sprudelstein*), from Carlsbad.

16. *Flos Ferri* (flower of iron), or fibrous arragonite, bluish-white, sometimes of a silvery lustre, branched and aggregated like coral, from the clefts of spathic ironstone in Styria.

17. *Stalactite*, peg-shaped calcite of radiated structure, from the fossiliferous mussel-chalk at Wieslock in Baden.

18. *Pea-Stone*, globular, partly calcareous stalactite, containing red or iron ochre, the peas formed in concentric layers, from the hot-springs of Carlsbad.

PLATE VIII.

FIGS. 1—9.—MARBLES.

1. *Ruin Marble*, cut and polished perpendicularly to the planes of the layers; the vertical displacement of the individual dark-coloured layers is marked by right lines which correspond to the vertical cleavage, from Tuscany.
2. *Fire Marble*, or *Lumachelli*, polished, containing the remains of shells, a fragment of which is distinguished by play of colours in red, yellow, and green, which is probably due to a fossil Nautilus (*Ammonite*), from Carinthia.
3. *Red Marble*, brecciated, from Northern Italy.
4. *Pale yellow Marble*, from Florence.
5. *Black and white mottled brecciated Marble*, from the mountain limestone of Ardennes.
6. *Blackish-grey Marble*, enclosing petrified volutes (*pyramidella turbinella*), from the tertiary formation.
7. *Grey Marble*, with dark streaks, from Italy.
8. *Red, green, and white-coloured breeciated or fragmentary Marble*, from Sicily.
9. *Variegated Marble*, enclosing corals, from the transition rocks of Nassau.

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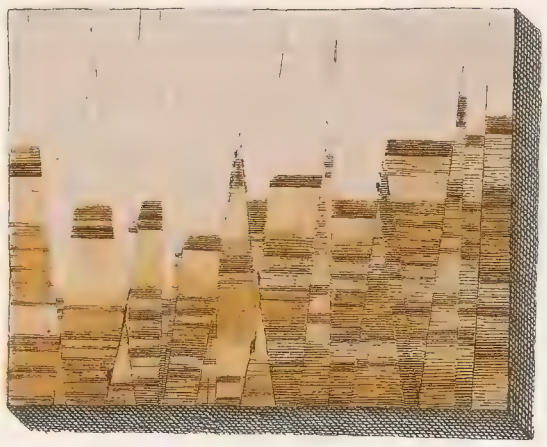

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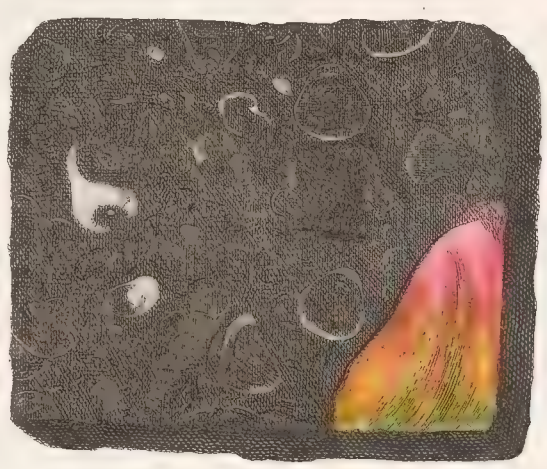

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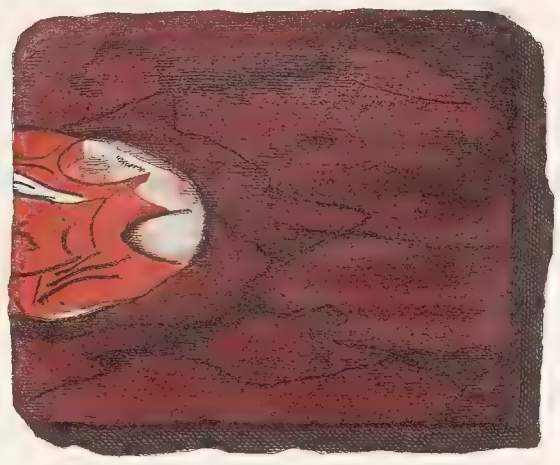

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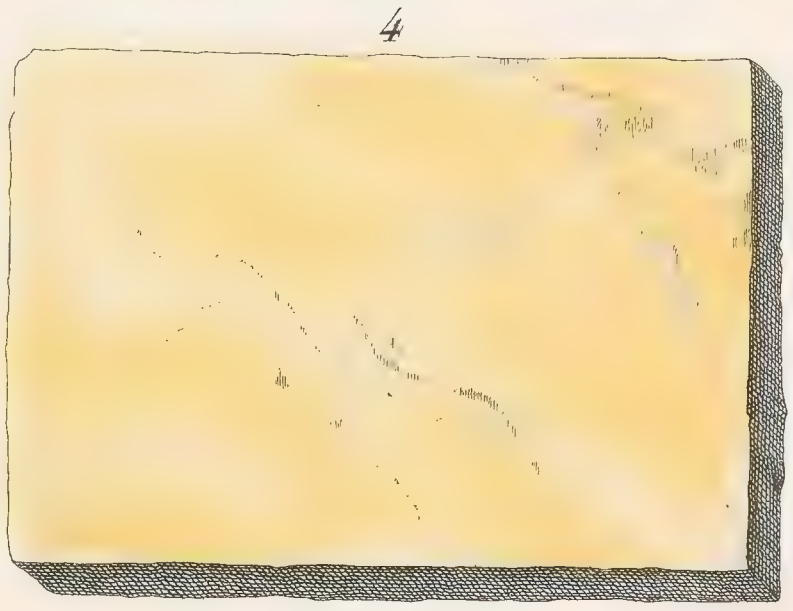

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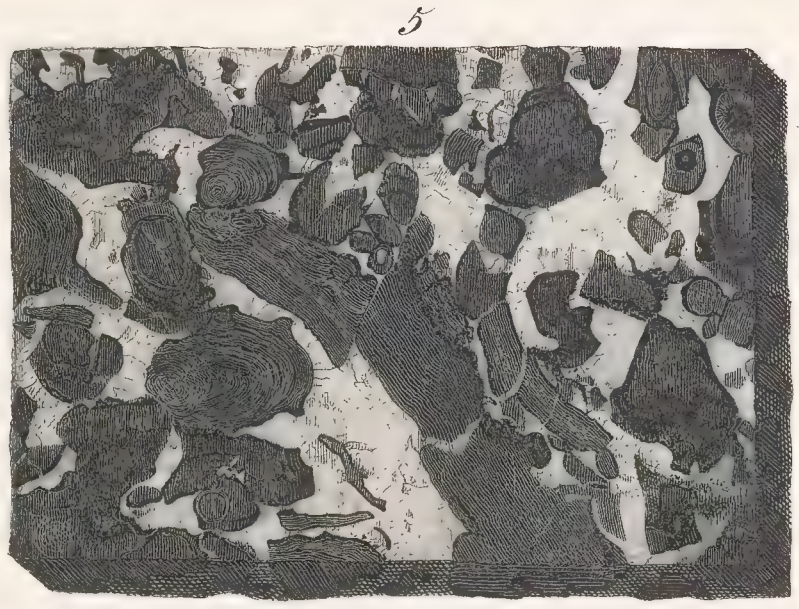

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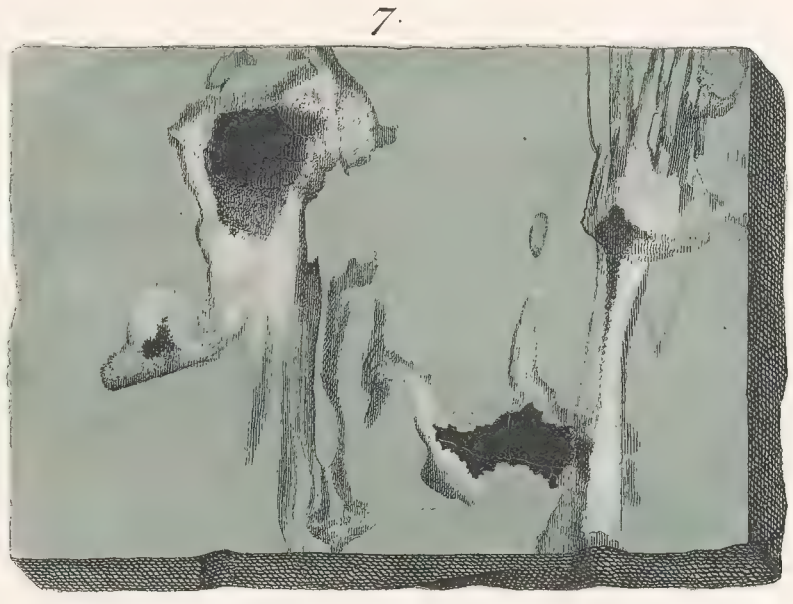

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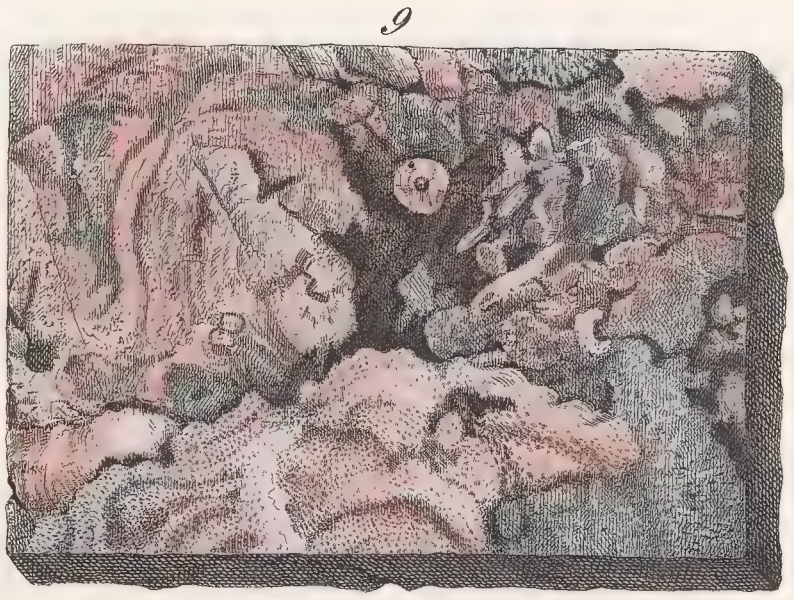

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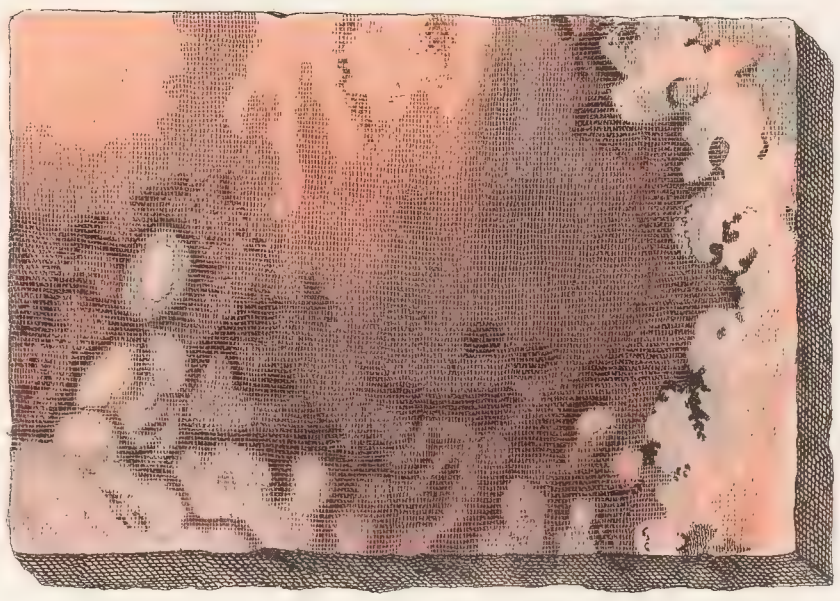

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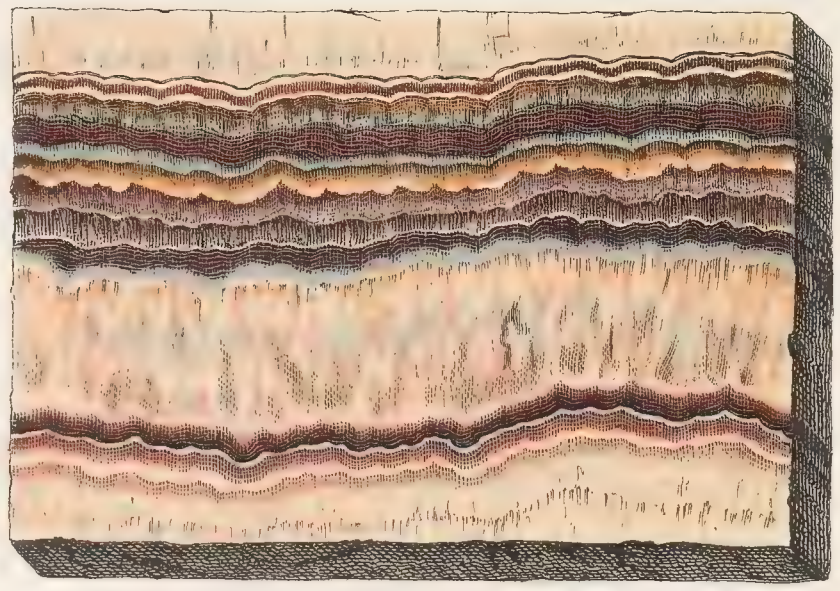

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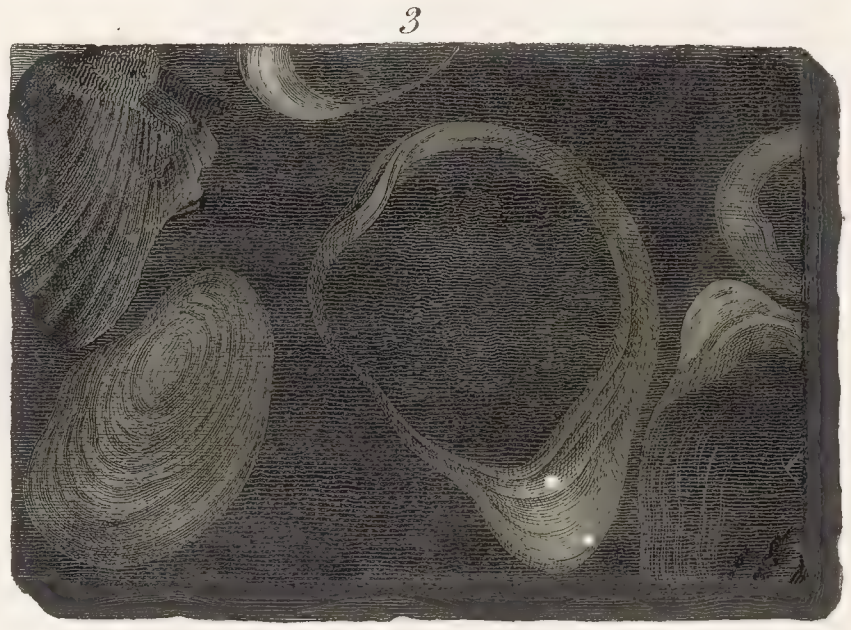

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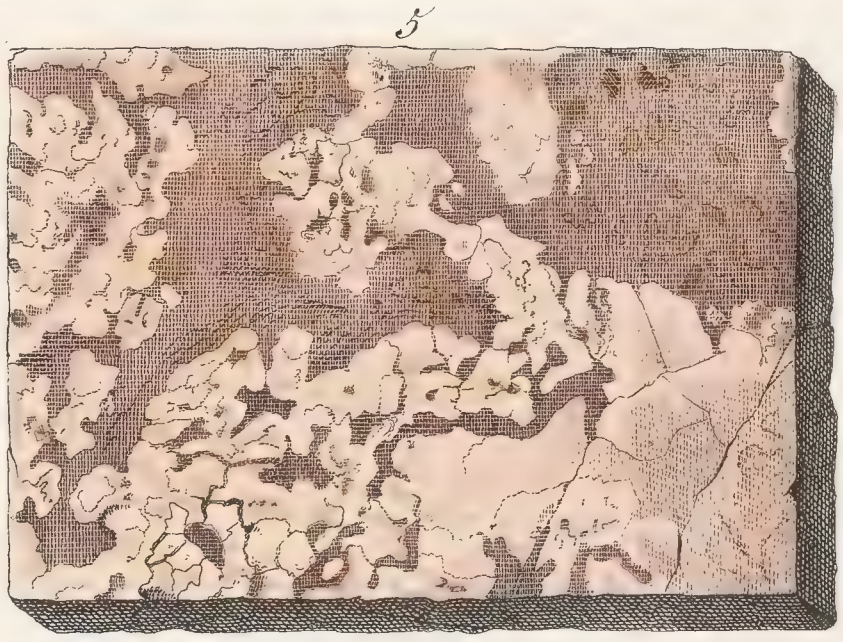

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PLATE IX.

Figs. 1—8.—Carbonate of Lime, Marble.

1. *Red-mottled Marble*, tertiary fresh-water limestone, altered by volcanic minerals, cut parallel to the planes of the layers, from Böttingen near Münsingen in the Swabian Alps.
2. *The same*, cut perpendicularly to the planes of the layers, from the same locality.
3. *Gryphitic Limestone*, the limestone of the lower lias, with *gryphæa arcuata* enclosed, from Baihingen on the Fildern.
4. *Variegated Fragmentary Marble*, tertiary brecciated limestone, from Bigorre in the Pyrenees.
5. *Reddish-yellow and bluish-red mottled Marble*, from the middle white Jura of Bissingen below Teck in Würtemberg.
6. *Pale yellow and violet flaked Marble*, from the same locality.
7. *The same*, violet and yellow, same locality.
8. *The same*, dark-yellow and yellowish white, from the same place. All (Figs. 5—8) from the neighbourhood of volcanic rocks at the northern slope of the Swabian Alps.

PLATE X.

Figs. 1—3.—Arragonite.

1. *Crystal of Arragonite*, double twins, a right rhombic prism, with truncation of the acute lateral edges and of the acute angles, yellowish-white, transparent, from Waltsch, in Bohemia.

2. *Reddish Arragonite*, rhombic prism, with truncation of the acute lateral edges, from Molina in Arragon. These crystals are composed of numerous smaller ones, so arranged, however, that individual planes appear to be lustrous.

3. *Crystallised Arragonite*, a druse of rhombic pyramids, acicular and spear-like, from Leogang in Salzburg.

Figs. 4—6.—Brown Spar, Bitter Spar, Carbonate of Lime, with Protoxide of Iron and Manganese.

4. *Reddish-brown spar*, the so-called ankerite, from the lodes of micaceous schist at Schneeberg in the Erzgebirge.

5. *Compact-brown spar*, striped with white, yellow, and green, so-called agate marble from Algiers, frequently cut and used as marble in Paris.

6. *The same*, with brown undulations, from Gibraltar.

Figs. 7—10.—Gypsum, Hydrous Sulphate of Lime.

7. *Gypsum*, primary form an oblique rectangular prism.

8. *The same*, with truncation of all the basal edges, an oblique rectangular octahedron, from Derbyshire.

9. *The same*, two crystals aggregated as twins, from Bex in Switzerland.

10. *Splinter of a lenticular twin*, yellowish-white, from the gypsum quarries of Paris.

Figs. 11 and 12.—Anhydrite, Anhydrous Sulphate of Lime.

11. *Anhydrite*, a right rectangular prism, with truncation of the right angles, from Salzburg.

12. *Reddish Anhydrite*, primary form, a right rectangular prism ; the cleavage in three different directions is indicated on the lateral planes, from Hallein in Salzburg.

Figs. 13 and 14.—Apatite, Phosphate of Lime.

13. *Apatite*, primary form, a regular hexagonal prism, from Schlackenwald in Bohemia.

14. *The same*, green, the hexagonal prism in combination with truncation of all the basal edges (first hexagonal double pyramid), and of all the angles (second acute hexagonal double pyramid), from the same locality ; still more composite crystals, with double and triple truncation, are found at St. Gothard and in the Tyrol.

Figs. 15—18.—Fluor Spar, Fluoride of Calcium, or Fluate of Lime.

15. *Fluor spar*, a regular octahedron, bounded by eight equal-sided triangles, the primary form. Is found rose-red at St. Gothard, in the Canariathal, and in Unterwalden ; green at Breitenbronn in Saxony.

16. *Fluor spar*, yellow, cube with truncated angles, from Saxony.

17. *The same*, dichromate, by reflected light blue, and by transmitted light emerald-green ; twins, a cube with doubly truncated edges (pyramidal cube), half the natural size, from Derbyshire.

18. *The same*, cube with triple pointing of angles (48-sided figure), from the Münsterthal, near Freiburg in Breisgau.

Tab. X.

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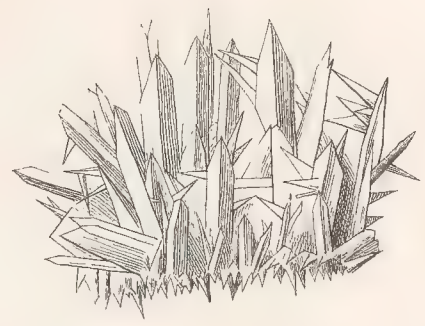

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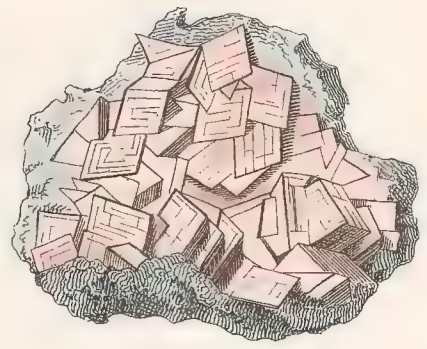

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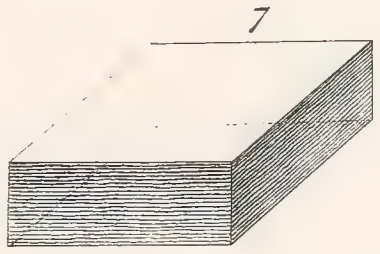

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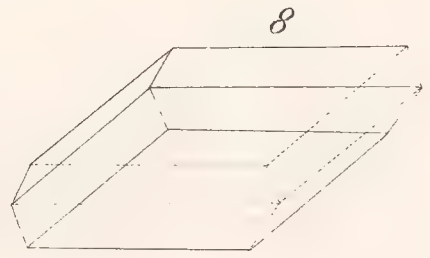

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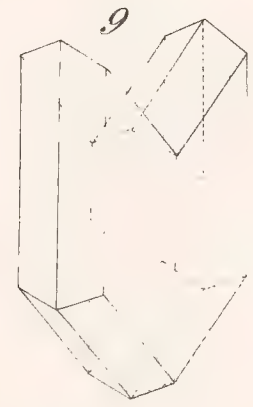

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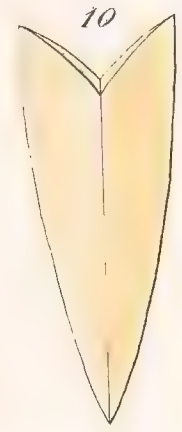

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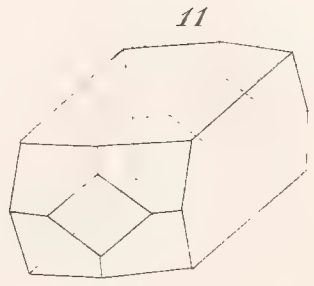

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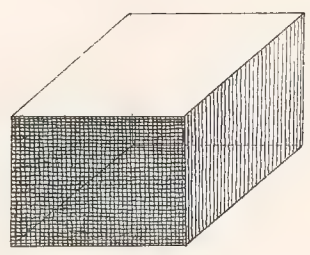

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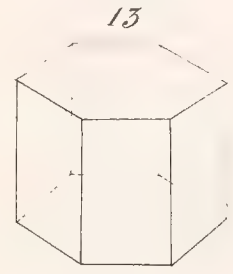

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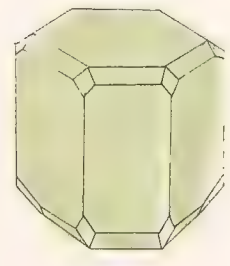

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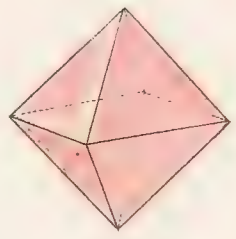

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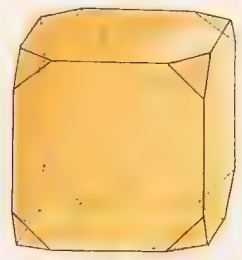

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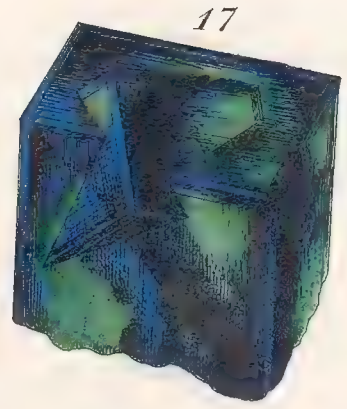

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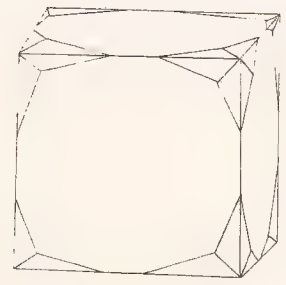

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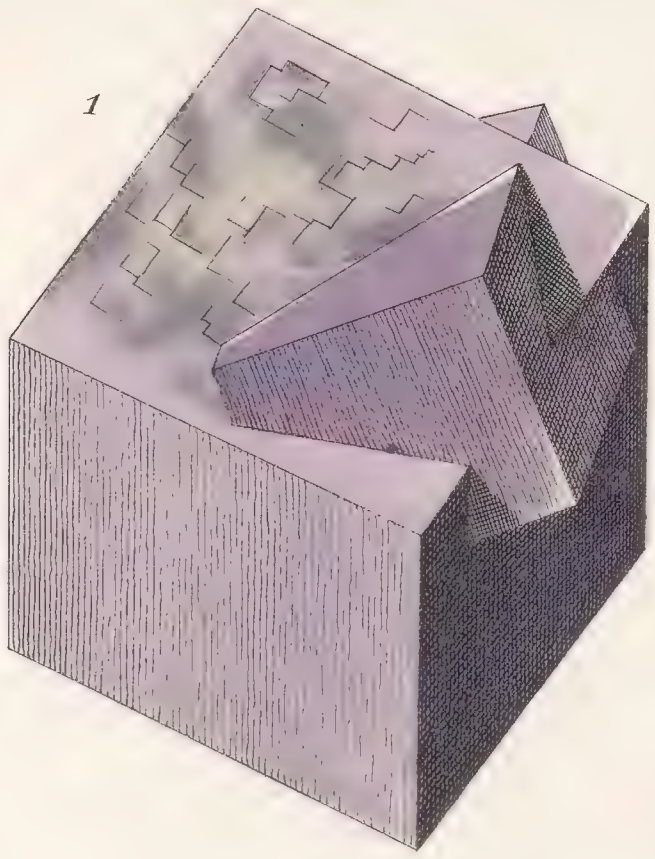

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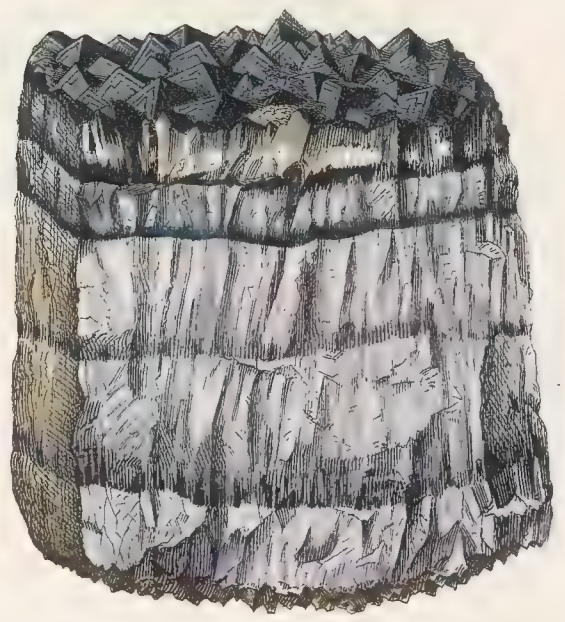

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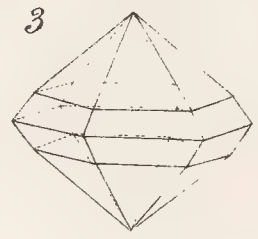

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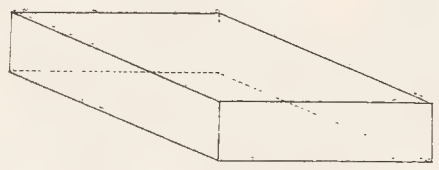

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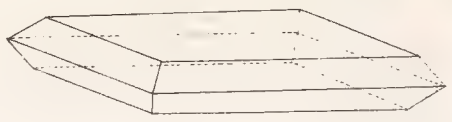

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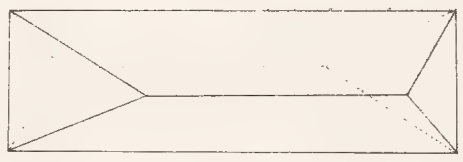

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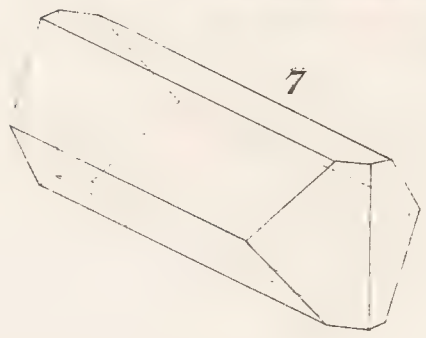

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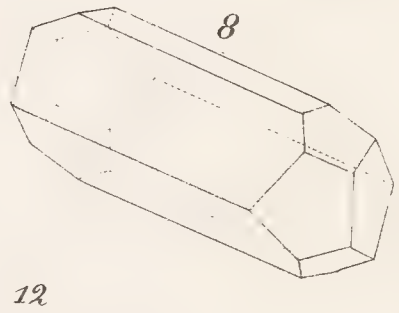

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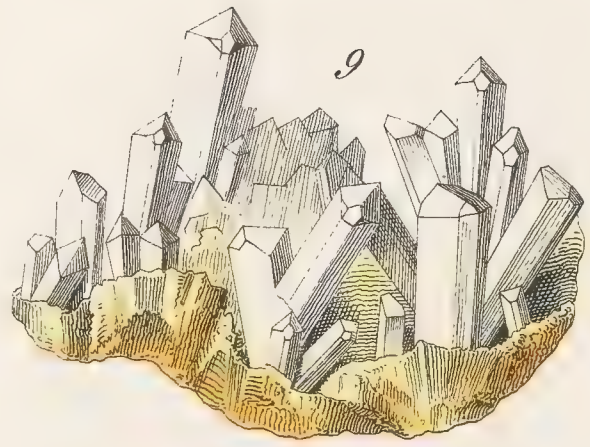

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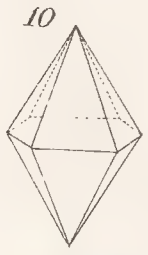

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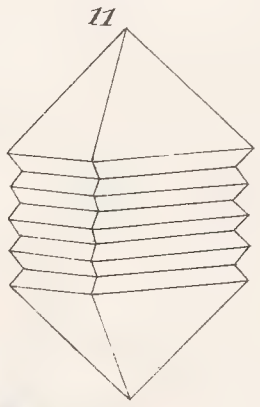

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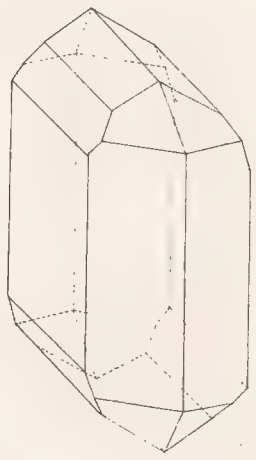

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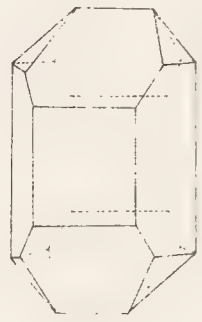

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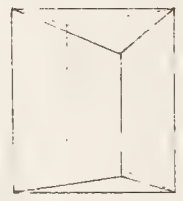

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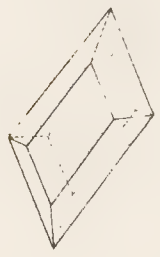

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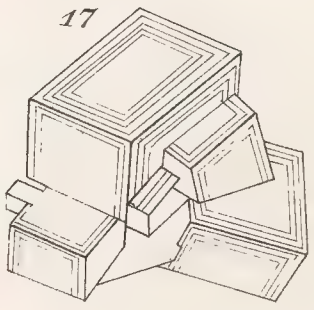

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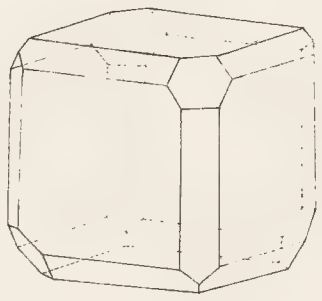

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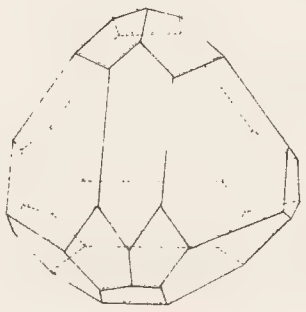

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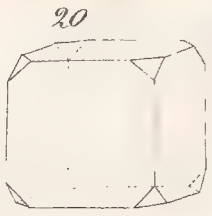

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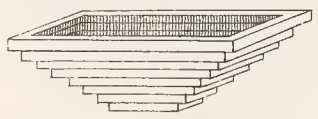

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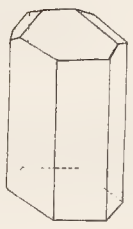

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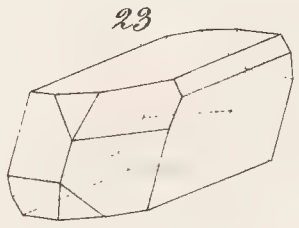

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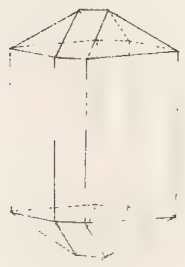

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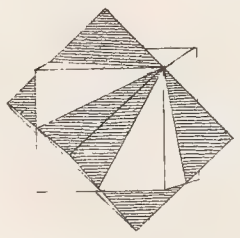

PLATE XI.

Figs. 1 and 2.—Fluor-Spar.

1. *Fluor-Spar*, violet, perfectly transparent; two large cubes united as twins. On the upper surface the planes of single small cubes are visible. From Cumberland.

2. *Fluor-Spar*, in attached crystals, striated violet and white. On the upper surface separate cubic planes are seen. Also from Cumberland. Is manufactured in England into cups, and all kinds of small objects of art.

Figs. 3—6.—Baryta Compounds.

3. *Witherite*, carbonate of baryta, double hexagonal pyramid, originating from the right rhombic prism by double truncation of the basal edges and of the acute basal angles.

4. *Barytes*, sulphate of baryta, primary form, a right rhombic prism, tabular. From Hungary.

5. *The same*, with truncation of all the basal edges. From the veins of variegated sandstone of the Schwarzwald.

6. *The same*, a horizontal prism, with truncation of the obtuse angles, to the extent of causing the terminal planes to disappear. From Auvergne.

Figs. 7—9.—Strontia.

7. *Celestine, Sulphate of Strontia*, a horizontal prism. The right rhombic prism is so truncated at the obtuse angles that the terminal planes are still visible. From Girgenti, Sicily.

8. *The same*, with truncation of the acute and of the obtuse angles. Also from Girgenti.

9. *The same*, aggregated in a druse on native sulphur. The crystals are obliquely upright; the obtuse angles are simply, and the acute ones doubly, truncated. From the same locality.

Figs. 10—13.—Salts of Potash.

10. *Sulphate of Potash*, a rhombic prism, converted by truncation of the basal edges and of the acute angles, into an hexagonal double pyramid; the product of manufacture.

11. *Potash Alum*, or sulphate of alumina and potash, a regular octahedron; five crystals like a staircase above one another; a product of manufacture.

12. *Saltpetre*, nitrate of potash, right rhombic prism, with truncation of the obtuse lateral edges, double truncation of the obtuse angles and simple truncation of the basal edges.

13. *The same*, rhombic prism with truncation of the obtuse lateral edges, of the obtuse angles, and of the basal edges; combination of the hexagonal prism with the hexagonal double pyramid of the rhombic system.

Figs. 14—17.—Salts of Soda.

14. *Trona*, native sesquicarbonate of soda, with four equivalents of water; an oblique rhombic prism, with truncation of the obtuse basal angles, from Merida in Columbia.

15. *Soda*, simple carbonate of soda, with ten equivalents of water, an oblique rhombic prism, with truncation of the basal edges (oblique rhombic octahedron), an artificial crystal.

16. *Fibrous Rock-Salt*, coloured red by oxide of iron, from the lower surface of the rock-salt in the shell-limestone at Wilhelmsglück, in Swabia.

17. *Nitrate of Soda*, obtained by crystallization from the Chili saltpetre rhombic hexagon, with ladder-like arrangement of the crystalline planes aggregated in a druse.

Figs. 18 and 19.—Borate of Magnesia.

18. *Boracite*. The primary form is a tetrahedron, plainly marked at the alternate angles of the cube by hexagonal planes, the edges of the cube truncated (a combination of the tetrahedron with the cube and rhombic), from the gypsum of Lüneburg.

19. *Boracite*, tetrahedron, cube and pyramidal tetrahedron, from the same locality.

Figs. 20—25.—Salts of Soda—*continuation*.

20. *Rock-Salt*, chloride of sodium, primary form, a cube with truncated angles, from Salzburg.

21. *Kitchen or Table Salt*, as it is separated by evaporation of brine in the salt-pans, scalariform arrangement of the segments of the cube, hollowed out like a funnel in the middle.

22. *Tincal*, native borate of soda, primary form an oblique rhombic prism, with truncation of the obtuse lateral edges and of the acute basal edges.

23. *Glauberite*, native sulphate of soda, primary form an oblique rhombic prism, with truncation of the basal edges, angles, and lateral edges.

24. *Epsomite*, sulphate of magnesia with seven equivalents of water, right rhombic prism, primary form, with truncation of the basal edges (rhombic octahedron) and of two vertical and lateral edges; artificial product.

25. *Sal-Ammoniac*, chloride of ammonium, cube, twins, both crystals so united that the edges of the cube diverge in a radiated manner; extracted from an animal oil in the manufacture of rough sal-ammoniac.

PLATE XII.

Figs. 1—3.—Sulphur.

1. *Native Sulphur*, rhombic octahedron, primary form, with truncation of the vertex and of the upper basal edges, from Girgenti in Sicily.

2. *The same*, with truncation of the two acute vertical edges, from the same locality.

3. *The same*, a rhombic octahedron with truncation of all the vertical and basal edges, of the acute basal edges, of the acute lateral angles, and triple truncation of the upper basal edges; combination of five different rhombic octahedrons with the half prism, from the same locality.

Fig. 4.—Honey-Stone.

4. *Honey-Stone* or *Mellite*, mellate of alumina with fifteen equivalents of water; primary form, a quadratic octahedron, from the brown coal at Arten in Thuringia.

Figs. 5—7.—Graphite.

5. *Graphite plumbago*, primary form, lower hexagonal prism or table, from the magnetic iron-stone disseminated in the gneiss of Arendal in Norway.

6. *Clear yellow transparent Amber*, roundish mass of a remarkable resinous lustre and conchoidal fracture, enclosing several flies, from the coast of the Baltic, near Dantzic.

7. *Brown red Amber*, in the tertiary sandstone of Carpathia.

Figs. 8—10.—Coal.

8. *Anthracite*, from the greywacke of Portsmouth, Rhode Island.

9. *Parrot* or *Cannel Coal*, compact, with rhombic segregation, of rare occurrence, in layers, from the lower coal-beds of Saarbrück.

10. *Pitch-glancing Coarse Slate Coal*, from the coal formation of Planitz in Saxony, known as pitch-coal.

Figs. 11—13.—Brown-Coal, Lignite.

11. *Acicular Brown-Coal*, bundles of vessels of the stems of palms, from the tertiary sand of Lobsann in Elsass.

12. *Earthy Brown-Coal*, with fossil seeds, from Salzhausen, the smaller oblong granules are the *Carpolithus minutulus* of Brown, the larger ones are nuts of the *Jugulans rostrata*, half converted into coal and partly opened.

13. *Bituminous Wood, Lignite*, or fibrous wood-coal, from the tertiary coal mines of Skoplau, at Colditz in Saxony.

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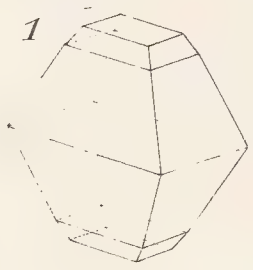

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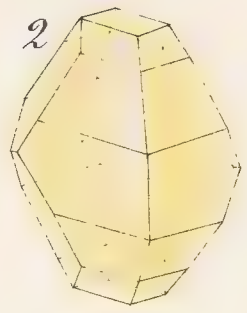

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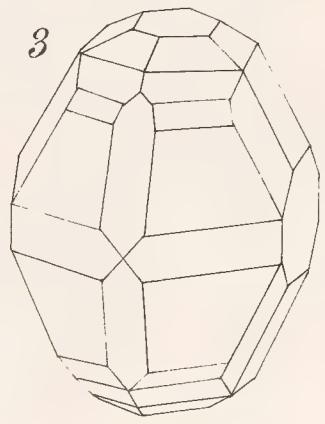

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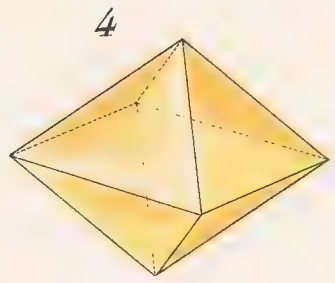

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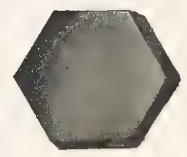

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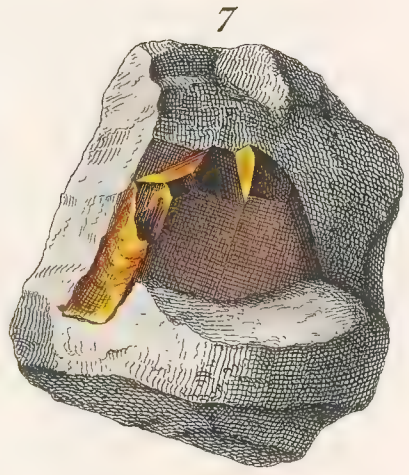

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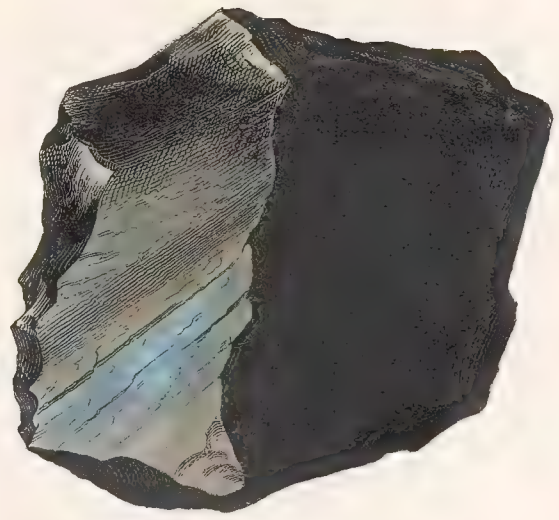

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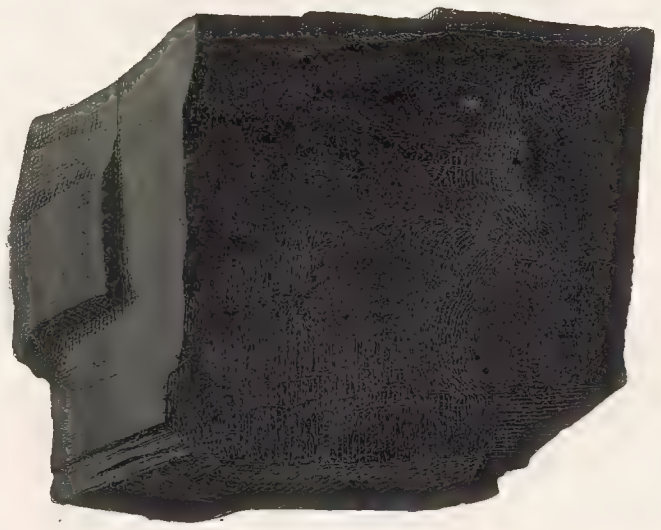

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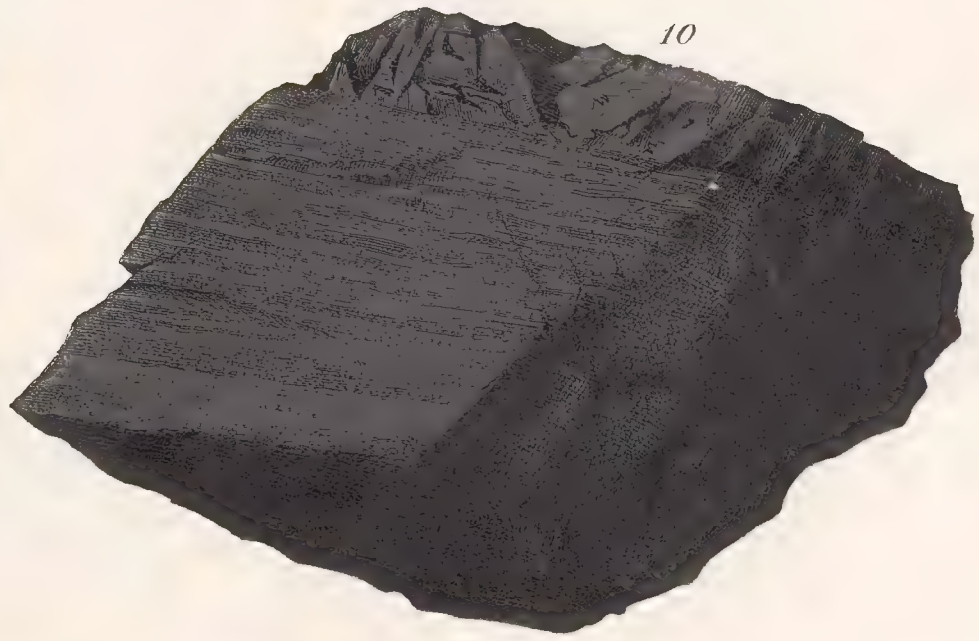

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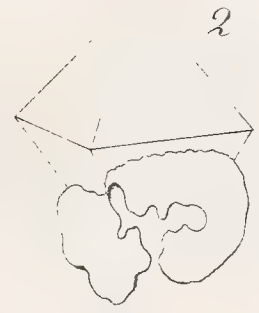

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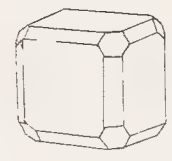

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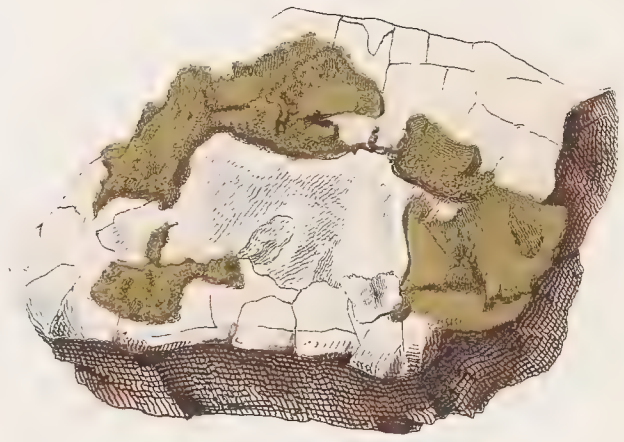

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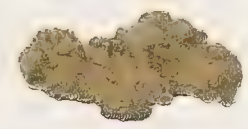

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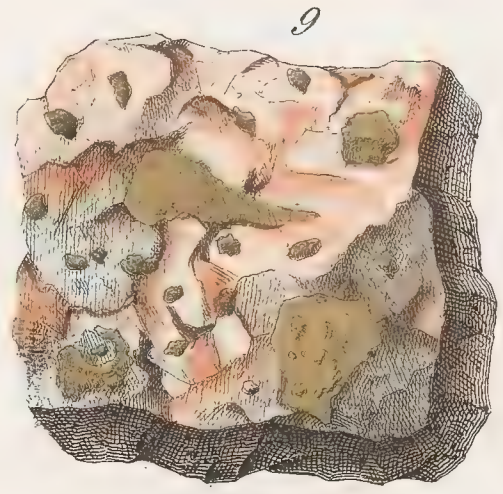

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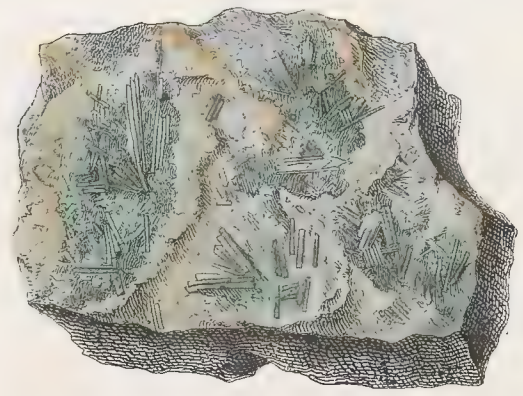

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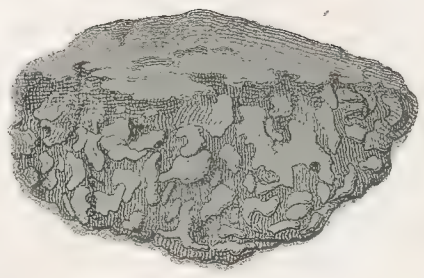

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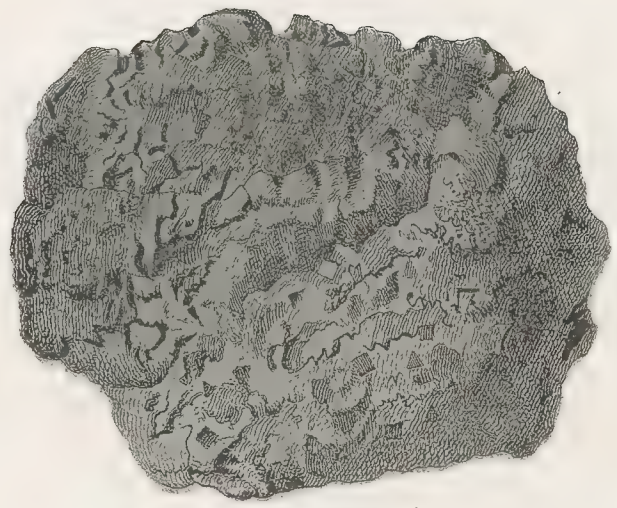

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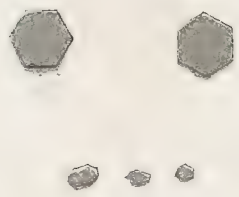

PLATE XIII.

Figs. 1—10.—Gold.

1. *Native Gold*, in roundish particles, as if melted together, imbedded in and encrusted on a finely granular reddish quartz, from San Francisco, California.

2. *Crystal of Gold*, a regular octahedron, the primary form perfectly formed above, with roundish melted grains below, of the natural size as it was, according to F. Alger, found a few years ago in California. This native gold contains 87·5 to 88·5 of gold, the rest is silver with traces of copper and iron.

3. *The same*, a cube with truncation of the angles (octahedron), and of the edges (rhombic dodecahedron) as sometimes found, but smaller and more irregular, in Brazil.

4. *Native Gold*, in thin, crystalline, leaf-like laminae, on reddish quartz, from Vöröspatak in Siebenburg. This contains 60·49 of gold, and 38·74 of silver.

5. *Gold Nugget*, of a rounded oblong form in a reduced scale, declared to be the largest piece of native gold yet found at Victoria diggings in Australia, weighing 27 pounds 6 ounces, and 11 inches in length by 5 broad.

6. *Small Nugget of Gold* from the clayey sandy alluvium of the Gold Coast, West Africa. It contains 86·80 of gold, and 11·30 of silver, with traces of copper.

7. *Grains of Gold* of different forms and sizes, all flat and bearing marks of attrition, from the gold sand of San Francisco.

8. *Gold-dust* as it is most frequently obtained by washing, from the foot of the Urals.

9. *Smooth Gold*, in grains of different size, imbedded in a reddish finely granular quartz, from Victoria, Australia.

10. *Telluric* or *Graphic Gold*, a combination of 59·97 of tellurium with 26·97 of gold and 11·47 of silver; one of the few specimens of actually mineralised gold, from Offenbanya in Siebenburg, Transylvania. The crystals are small right rhombic prisms, arranged in a radiated manner, firmly united to reddish quartz.

Figs. 11—13.—Platinum.

11. *Native Platinum*, in small, lenticular, polished granules, from Choco in Brazil, where it is obtained along with gold, etc., by washing the sand. It contains 86·16 platinum, 8·03 iron, 1·09 iridium, 2·16 rhodium, 0·35 palladium, 0·97 osmium, 0·40 copper.

12. *Native Platinum*, a roundish mass, above, as it were polished, with irregular cavities at the side, which contain a darkish grey substance, the irite of Hermann, consisting of the oxides of iridium, osmium, iron and chromium, $2\frac{1}{4}$ oz. in weight, from Nischne Tagilsk, in the Urals.

13. *Native Platinum*, of the natural size, almost two pounds in weight, from the same locality.

Fig. 14.—Iridium.

14. *Osm-iridium*, or *Iridosmine*, in small hexagonal plates and irregular flattened grains, from the platinum sand of the same place.

PLATE XIV.

Figs. 1—5.—Native Silver.

1. *Native Silver*, in extended partially prismatic and curved branches, silver white, dim, with small crystals of magnetic quartz on yellowish calcite, from Kongsberg, Norway.

2. *The same*, cubes superimposed on each other, perfectly smooth, partially foliated, from the same place, of very recent occurrence.

3. *The same*, aggregation of cubes and quadratic tables, partially marked with octahedral structure, from the same place.

4. *Native Silver*, laminated, the plates a line in thickness, with arborescent markings, partly filiform at the edges, partly bordered by crystals, rhombic dodecahedrons, octahedrons and cubes, with a reddish tarnish; of earlier occurrence (between 1780-90), from Kongsberg.

5. *Native Silver*, arborescent, or reddish heavy spar, the branches consisting of octahedrons placed on one another, from Heinrichsgang at the Anton Mines, at Wolfach in the Black Forest. Occurrence, in 1836.

All the silver-ores are figured of their natural size.

Figs. 6—8.—Antimonial Silver.

6. *Antimonial Silver*, primary form a right prism, with truncation of the acute lateral edges.

7. *The same*, simple rhombic prism imbedded in heavy spar; both from St. Wenzel in the Schwarzwald.

8. Finely granular *antimonial silver*, containing 84% of silver, and 16% of antimony, also embedded in heavy spar, from the same locality.

Figs. 9—16.—Sulphuret of Silver, Glance and Red Silver Ore.

9. *Glance Silver*, primary form a cube, arranged in a druse, containing 85 of silver and 15 of sulphur, from St. Wenzel, near Wolfach.

10. *The same*, cube and octahedron, elongated and wedge-shaped, from St. Anton, in Heubachthal, near Wolfach.

11. *Brittle Glance Silver*, or *Melan Glance*, prismatic black silver, right rhombic prism, with truncation of the acute lateral edges, several crystals arranged in a group, from Freiberg in Saxony.

12. *Polybasite*, the primary form a rhombic hexagon; the figure represents a secondary hexagonal prism, with truncation of all the basal edges.

13. *Dark-red*, or *Ruby Silver*, antimony, silver-blende, the primary form a rhombic hexagon; combination of different acute and obtuse rhombohedrons in a group of crystals, from Andreasberg in the Hartz.

14. *The same*, various hexagonal prisms, arranged in a druse, from Freiberg in Saxony.

15. *Light-red, or Ruby Silver*, combination of the common with the obtuse rhombohedron and the hexagonal prism.

16. *The same*, unequal edged hexagonal double pyramid (scalenohedron), in combination above and below with the rhombohedron. Both kinds of forms occur at the Harz and Erz mountains.

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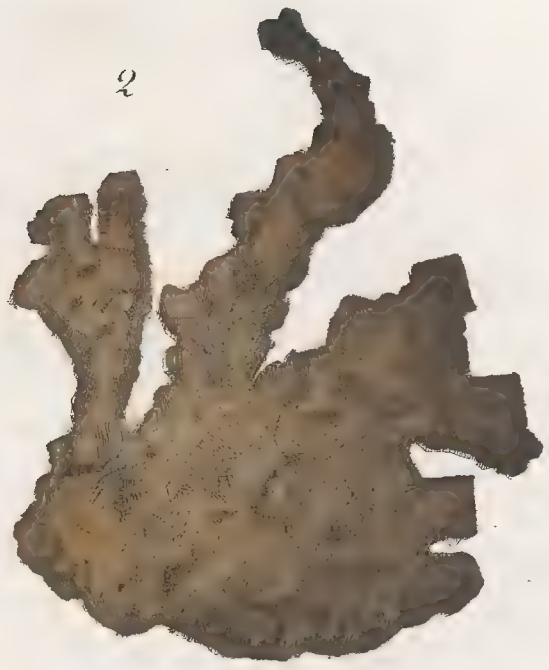

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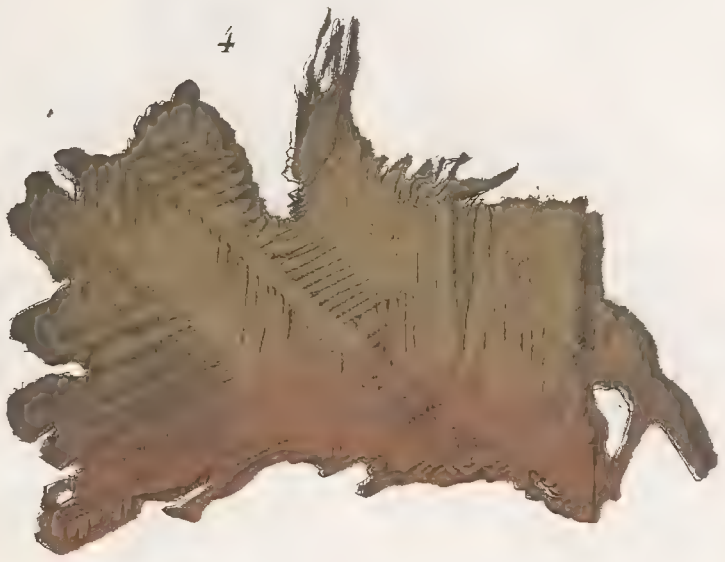

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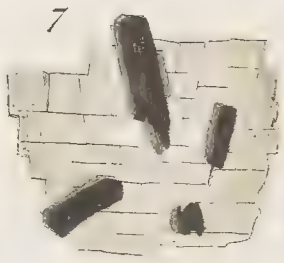

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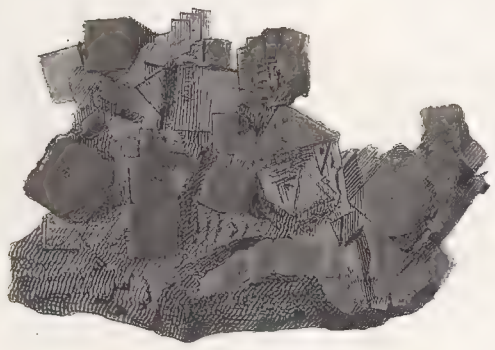

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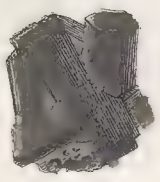

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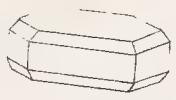

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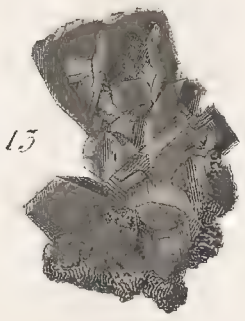

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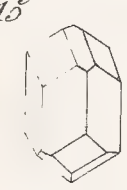

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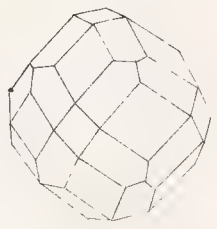

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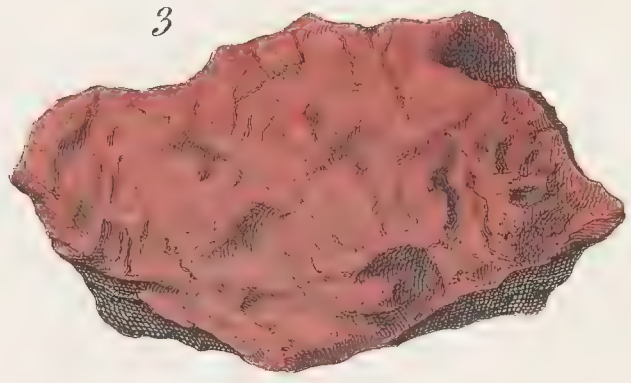

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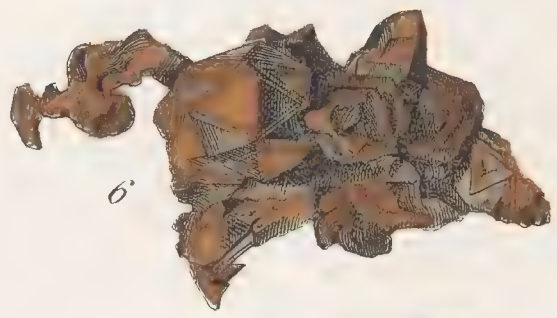

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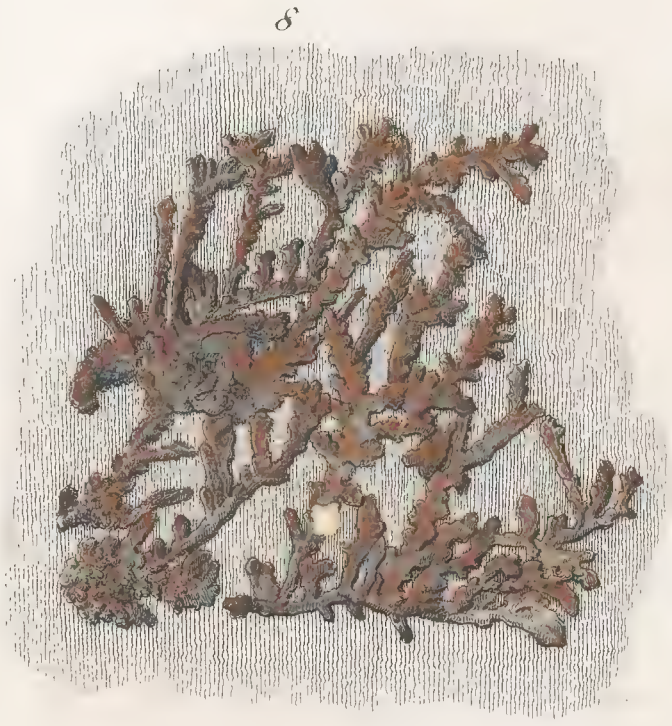

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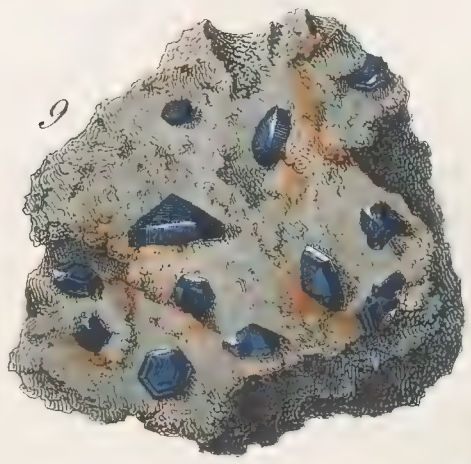

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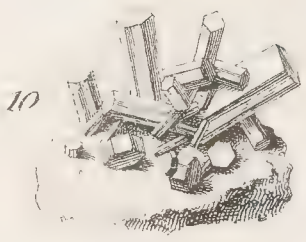

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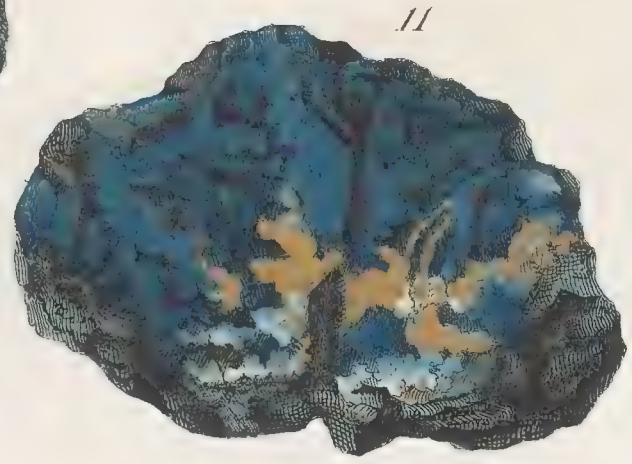

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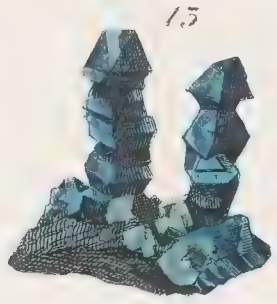

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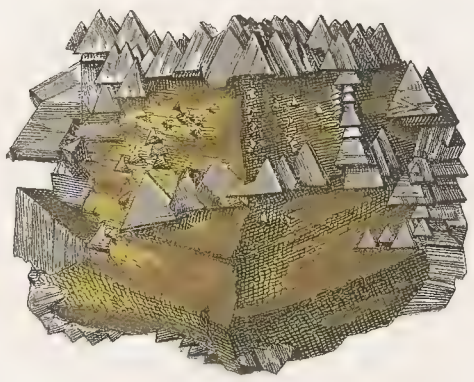

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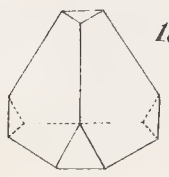

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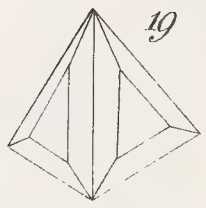

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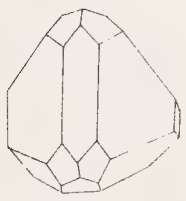

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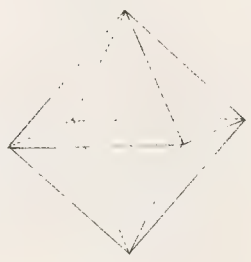

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PLATE XV.

Figs. 1—5.—Mercury, Quicksilver.

1. *Amalgam*, a compound of 36 of silver and 64 of mercury, the commonest form of crystal, a rhombic dodecahedron with truncation of all the edges (twenty-four sided solid), in combination with the planes of the cube, as it usually occurs at Moschel-Landsberg.

2. *Native Quicksilver*, in small globules on earthy cinnabar, from Stahlberg in the district of Saarbrück.

3. *Crystalline Cinnabar*, dark-red and dense, from Szlana in Hungary.

4. *Crystallised Cinnabar*, rhombic hexahedron, with double truncation of the vertex, combination of the acute rhombohedron, with two obtuse rhombohedrons, from Almaden in Spain.

5. *The same*, rhombohedral table, formed by truncation of the vertex, from Idria.

Figs. 6—20.—Copper Ore, Native Ore, and Sulphuret of Copper.

6. *Native Copper*, icosahedron, distinctly in combination with the cube, together with other crystals of the regular system, aggregated in an arborescent form, from Lake Superior, Michigan.

7. *The same*, octahedral, cubic, and dodecahedral crystals aggregated and distorted by the extension of individual planes, imbedded in granular quartz, from Katharinenberg.

8. *The same*, aggregated and branched like a tree (dendritic), with a slight coating of oxide of copper, from Cornwall.

9. *Copper Glance*, chalcosine or vitreous copper, in secondary hexagonal pyramids, with truncation of the basal edges (rhombic prism with truncation of the acute lateral edges and of the basal edges), partly aggregated as twins, and with an indigo-blue tarnish, on quartz, from Cornwall.

10. *The same*, rhombic prism, the primary form, with truncation of the acute lateral edges, same locality.

11. *Indigo Copper or Covelline*, simple sulphuret of copper, pulverescent, on copper pyrites, from Herrensegen, in the wilds of Schapbach in the Black Forest.

12. *Variegated Copper*, or *Erubescite*, compact, with violet and blue play of colours, from King David mine at Schneeberg in Saxony.

13. *Erubescite*, subsulphuret of copper with sulphuret of iron, containing 56·76 of copper, crystallised in regular octahedrons, with a drusy arrangement, from Cornwall.

14. *Copper Pyrites*, or *Chalcopyrite*, simple sulphuret of copper combined with sesqui-sulphuret of iron in equal proportions, containing 34·47 of copper, square octahedrons and quadratic tetrahedrons, with occasional twins, on yellowish brown-spar, from Cornwall.

15. *The same*, square octahedrons, the primary form.

16. *The same*, regular tetrahedrons with truncation of the angles, the combination with the second tetrahedron, the most usual form.

17. *Tetrahedrite* or *Grey Copper* (*fahl-ore*), in regular tetrahedrons, the primary form, drusy and imbedded in chalcopyrite, from the Harz.

18. *The same*, tetrahedrons with truncation of the angles, from Kapnik in Hungary.

19. *The same*, tetrahedron with double truncation of the edges, pyramidal tetrahedron, from the same place.

20. *The same*, tetrahedron with truncation of the edges (cube), and bevelling of the angles (second pyramidal tetrahedron), from the same place.

PLATE XVI.

Figs. 1—3.—Red Copper.

1. *Cuprite* or *red oxide of copper*, crystallised in regular octahedrons, the primary form, attached to dense crystalline foliated ore, from Siberia; contains 88·5 of copper.

2. *The same*, an isolated crystal, an octahedron with truncation of all the edges, from Chessy at Lyons.

3. *The same*, the edges at the junction of the octahedral faces being truncated, from the same place.

Figs. 4—7.—Blue Copper.

4. *Azurite* or *Chessylite*, composed of two equivalents of carbonate of copper and one equivalent of hydrous oxide of copper, in oblique rhombic prisms, with partial traces of malachite.

5. *The same*, a secondary monoclinic or clinorhombic table, with truncation of the obtuse lateral edges and of the obtuse angles, from the same place.

6. *The same*, with truncation of the basal edges and of the acute angles, same locality.

7. *The same*, radiated, dark blue, from a vein of the variegated sandstone of Neubulach, in the Black Forest of Würtemburg.

Figs. 8—12.—Malachite.

8. *Malachite*, *green carbonate of copper*, with one-half equivalent of water, an oblique-rhombic prism, arranged in a bundle, from the Herrensegen in the Schwarzwald or Black Forest.

9. *The same*, twins, composed of two half-oblique rhombic prisms, with truncation of the obtuse lateral edges, from Chessy.

10. *Fibrous Malachite*, in compact masses, sawed and polished, from Siberia.

11. *The same*, velvet-like lustrous radiating bundles of acicular crystals, on liver-coloured ore, from the Herrensegen in the Schapbachthal.

12. *Compact Malachite*, with tuberose surface, as it is used for all kinds of small objects of vertu when polished like No. 10, also from Siberia.

Figs. 13—15.—Phosphates of Copper.

13. *Phosphochalcite*, *Lunnite* or *hydrous-phosphate of copper*, arranged in a radiated manner in oblique-rhombic prisms, the primary form, on hornstone, from Rheinbreitenbach.

14. *Libethenite* or *octahedral phosphate of copper*, in rectangular octahedrons, on quartz, from Libethen in Hungary.

15. *The same*, with truncation of two vertical edges, united with the rhombic prism, same locality.

Figs. 16 and 17.—Silicate of Copper.

16. *Dioptase* or *emerald copper*, of drusiform arrangement in rhombohedrons, with truncation of the basal edges, on quartz, from Altyn-Tubeh in the Kirgisensteppe, Siberia.

17. *The same*, isolated crystal, from the same place.

Figs. 18—22.—Arseniates of Copper.

18. *Euchroite*, or *subarseniate of copper*, with four equivalents of water, in rhombic octahedrons, with a drusiform arrangement, on brown quartz, from Libethen in Hungary.

19. *Liroconite*, or *octahedral arseniate of copper*, with two and a-half equivalents of water, in rhombic prisms, with a drusiform arrangement, on quartz from Cornwall.

20. *The same*, isolated crystal, a right rhombic crystal, with truncation of the obtuse angles, from the same locality.

21. *Olivenite* or *prismatic arseniate of copper*, with two equivalents of water, a lower right rhombic prism, with truncation of the acute angle, from the same locality.

22. *Chalcophyllite* or *copper mica*, with three equivalents of water, a rhombohedron, with truncation of the vertex to a rhombohedral table, from Redruth in Cornwall.

Fig. 23.—Sulphate of Copper.

23. *Cyanosite* or *sulphate of copper*, with five equivalents of water, an oblique rhomboidal prism, the primary form, with truncation of the obtuse lateral edges, from the same place.

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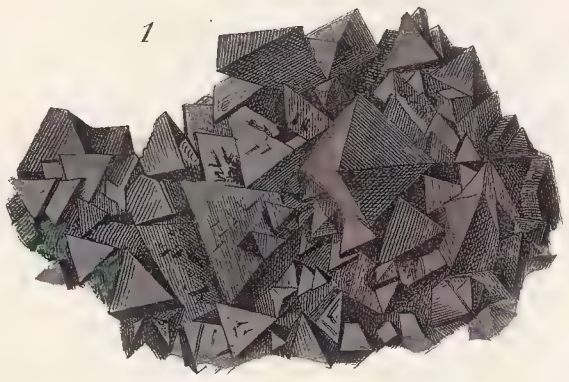

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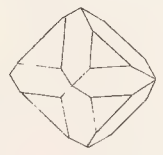

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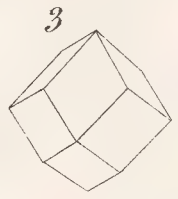

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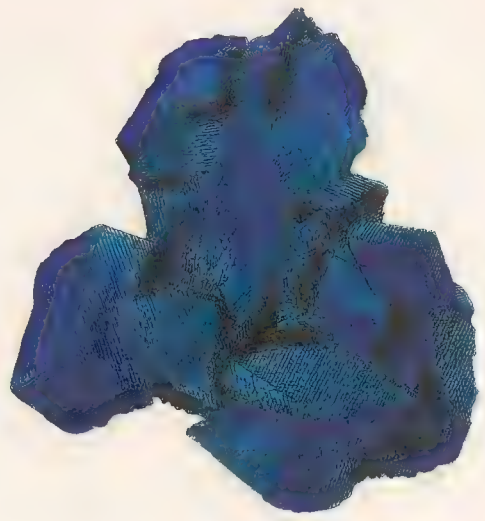

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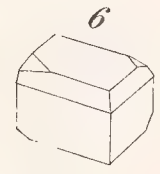

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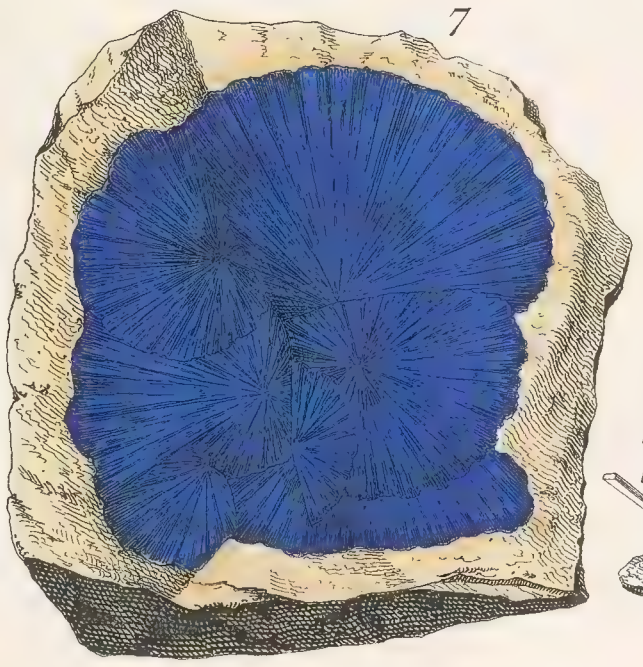

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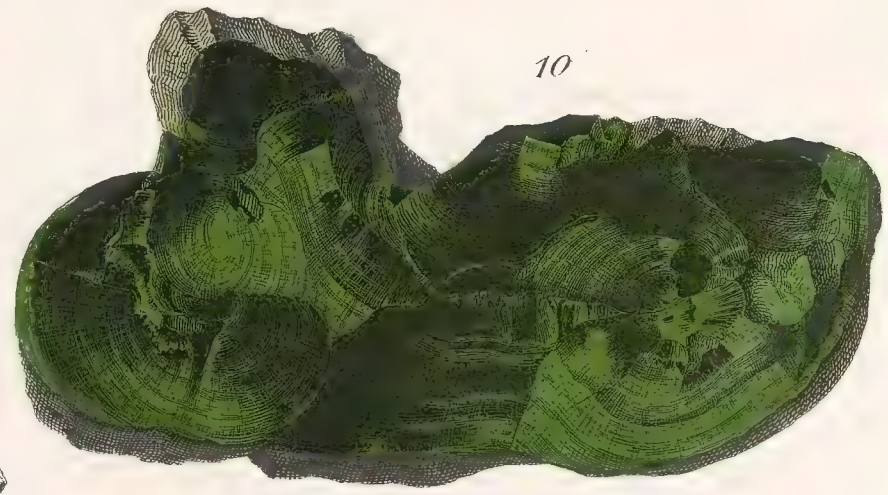

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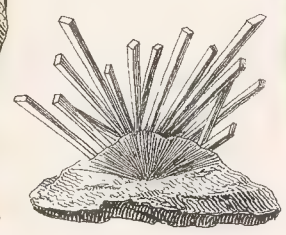

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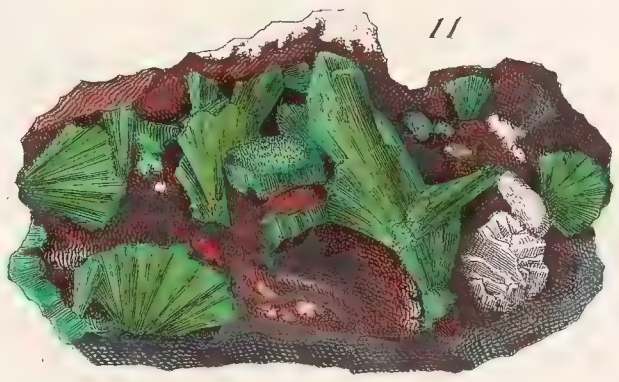

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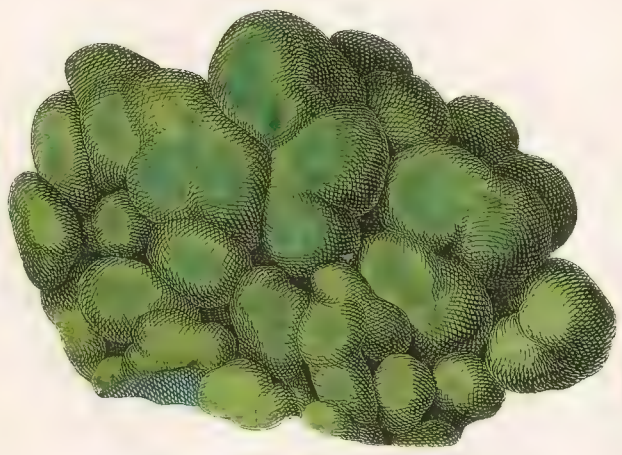

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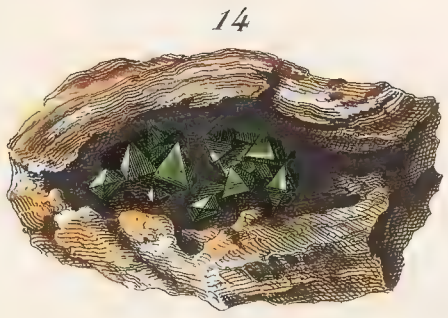

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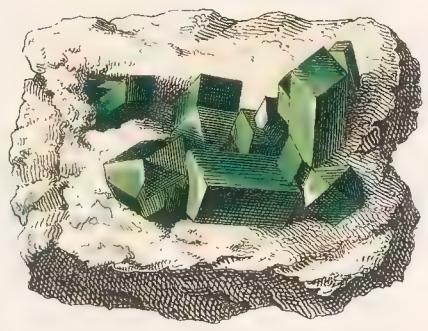

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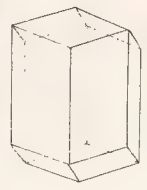

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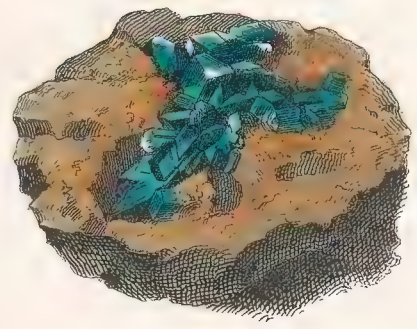

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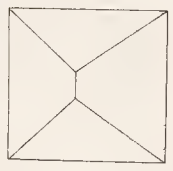

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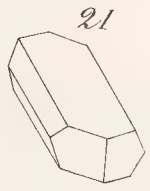

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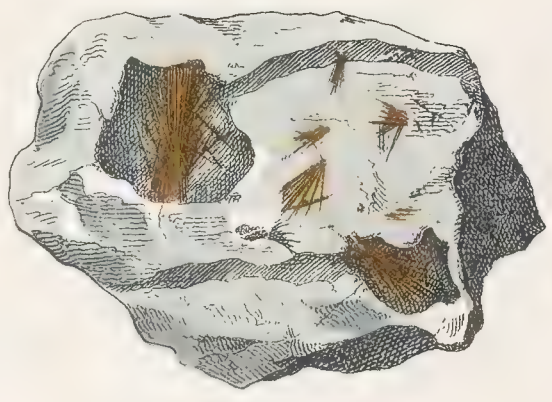

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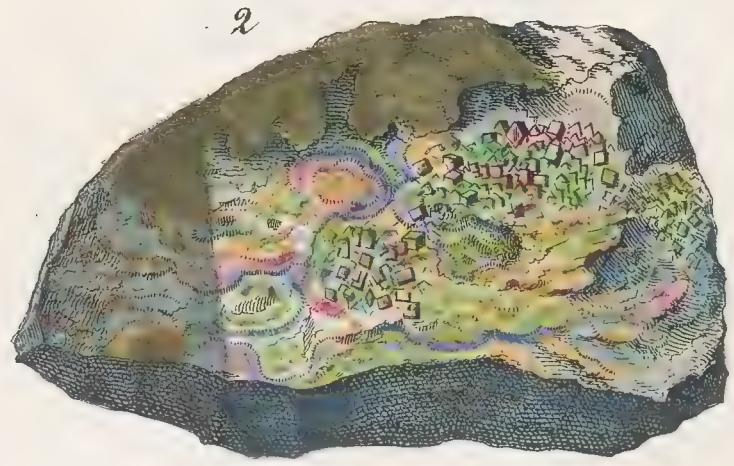

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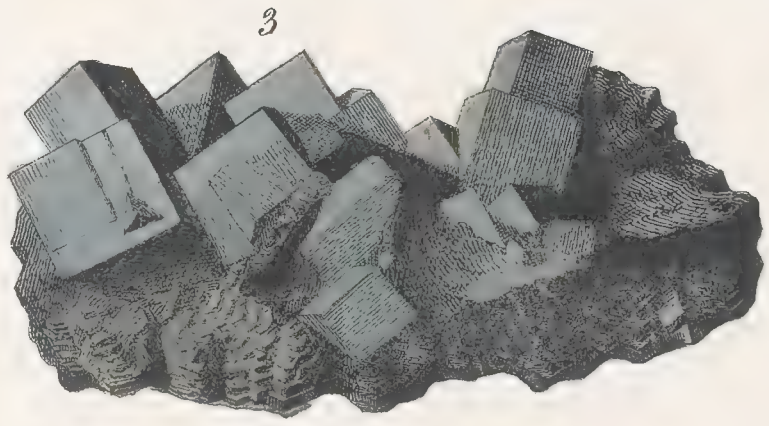

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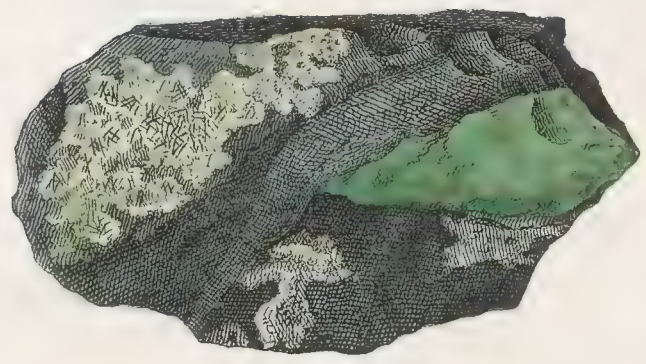

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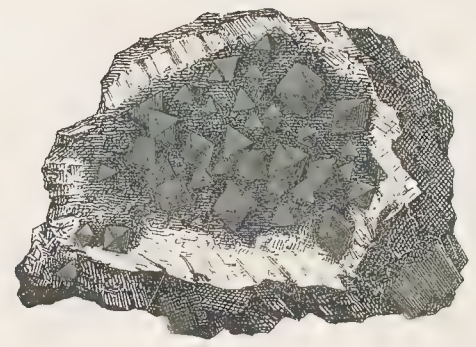

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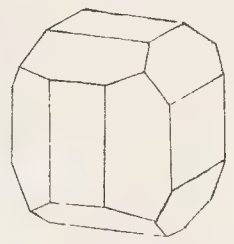

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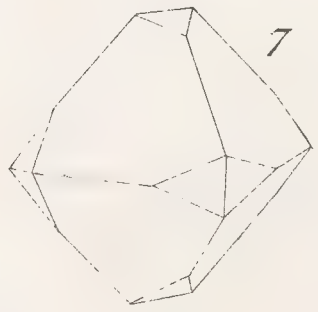

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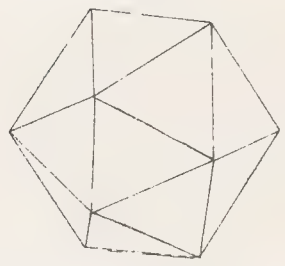

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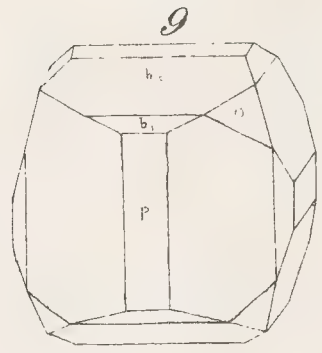

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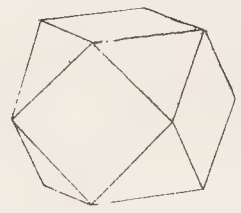

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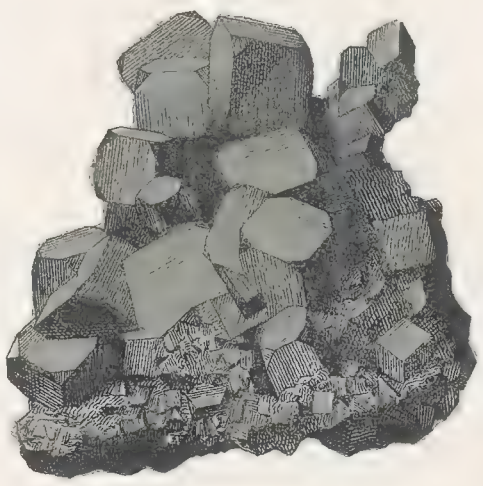

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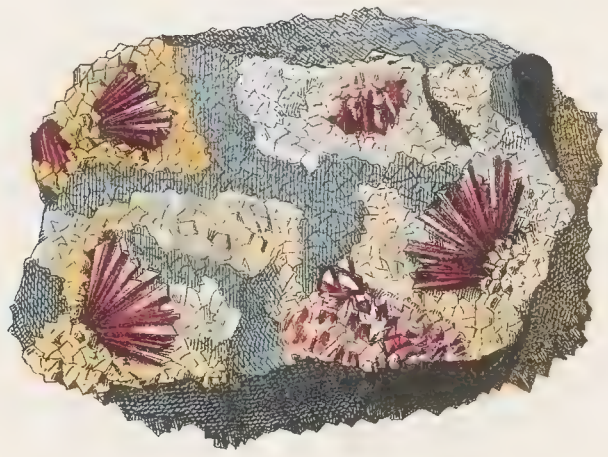

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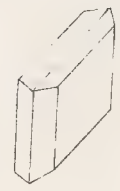

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PLATE XVII.

Figs. 1—4.—Nickel Ores.

1. *Capillary Nickel*, in small acicular bundles (hexagonal prisms), from the compact quartz or horn-stone of Johanngeorgenstadt in Saxony.
2. *Red Arseniet of Nickel*, compact, of a copper-red colour, with smaltine; it presents a variegated tarnish on the upper surface, and presents small cubic crystals. From Riechelsdorf in Hesse.
3. *Chloanthite*, or white nickel, containing cobalt, in cubes, from Schneeberg.
4. *Annabergite*, or *Nickel-ochre*, or carbonate of nickel, on chronic iron-stone, from Bashill, Baltimore.

Figs. 5—13.—Cobalt Ores.

5. *Cobalt-pyrites*, containing nickel in regular octahedral masses, from Müsen in Nassau.
6. *Cobalt-glance*, or *Cobaltine* (pentagonal dodecahedron, or twelve-faced pentagon), in combination with the cube.
7. *The same*, in combination with the octahedron.
8. *The same*, (icosahedron), both from Tunaberg in Sweden.
9. *The same*, cube, dodecahedron and octahedron, from the same place.
10. *Smaltine* or *Grey Cobalt*, cube, with truncated angles (octahedron).
11. *The same*, in a drusiform aggregation.
12. *Cobalt-bloom*, stellate and foliated, on horn-stone, from Schneeberg.
13. *The same*, oblique rectangular prism, with truncation of the lateral and terminal edges.

Figs. 14—17.—Iron.

14. *Meteorolite*, from Stannern in Moravia, enclosed in a fissured glass-like crust.
15. *Meteorolite*, from Aigle, polished, of earthy fracture and grey colour, sprinkled to some extent with nickel-iron.
16. *Meteoric iron*, studded over with grains of yellow and brownish olivine, which is partially decomposed, polished, from Atakama.
17. *Meteoric iron*, with crystalline structure, the so-called Widmannstadt figures, from Mexico.

PLATE XVIII.

Fig. 1.—Magnetic Pyrites.

1. *Magnetic Pyrites*, hexagonal prism, with transverse striation, from Kongsberg in Norway.

Figs. 2—8.—Pyrites.

2. *Pyrites*, twelve-faced pentagon, the usual form, from Traversella in Piedmont.
3. *The same*, cube and twelve-faced pentagon, from Herrensegen in the Schwarzwald.
4. *The same*, trapezoidal twenty-four-faced figure, from Traversella.
5. *The same*, regular octahedron, with drusy faces, from the Harz.
6. *The same*, arborescent aggregation of octahedrons, from Schneeberg.
7. *The same*, groups of cubes, with the peculiar striations in each of the two directions of the parallel edges, from Tavistock.
8. *Pyrites*, as the petrifying medium of an ammonite (*A. Amaltheus*), and a group of small crystals attached, cubes with truncation of the angles, from the lias schist at Boll.

Figs. 9—12.—Spear Pyrites.

9. A group of crystals of the *spear pyrites*, or *prismatic iron pyrites*, from Saxony.
10. *Spear Pyrites*, rhombic prism, the primary form, with truncation of the acute angles.
11. *The same*, united as twins, and stellate.
12. *The same*, rhombic octahedron, with truncation of the basal angles and terminal edges of Fig. 10.

Figs. 13—16.—Magnetic Iron.

13. *Magnetic Iron*, twins of two half octahedrons, from Pfitsch in the Tyrol.
14. *The same*, octahedral table, half octahedron, from the same locality.
15. *The same*, octahedron, with truncation of the angles (cube) and of the edges (rhombic dodecahedron), from Piedmont.
16. *Magnetic Iron*, crystallised in rhombic dodecahedrons, small group of crystals, from Traversella in Piedmont.

Figs. 17—21.—Iron-Glance, Red Oxide of Iron, Hæmatite.

17. *Iron-Glance* in the primary form, a rhombohedron, with truncation of the vertex, from Vesuvius.
18. *The same*, a rhombohedron, in combination with four other derived rhombohedrons, from the island of Elba.
19. *The same*, an hexagonal double pyramid in a tabular form, from St. Gothard.
20. *The same*, an hexagonal prism, the so-called *iron rose*, from St. Gothard.
21. *Fibrous Red-iron* or *hæmatite*, from Schwarzenberg in Saxony.

Figs. 22 and 23.—Brown Iron Ores.

22. *Needle Iron Ore* or Göthite, in right rhombic prisms, with truncation of the angles and basal edges, from Cornwall.
23. *Fibrous Limonite*, of a yellowish-brown colour, stellate and compact, from Thuringia.

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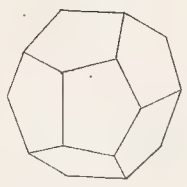

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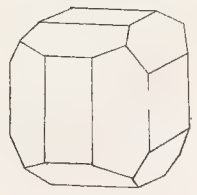

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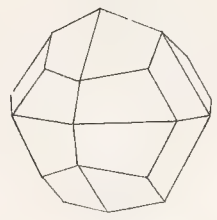

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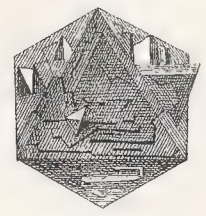

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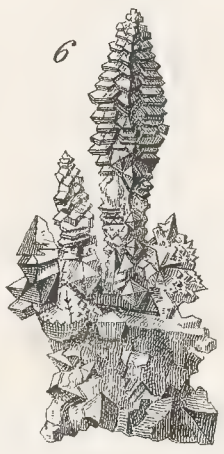

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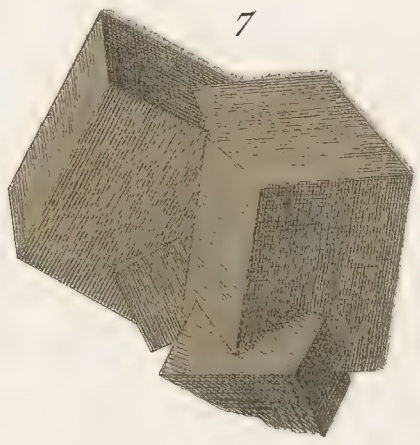

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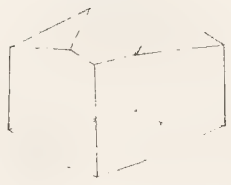

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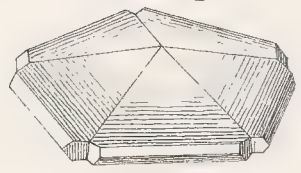

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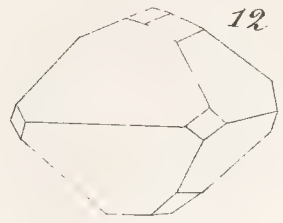

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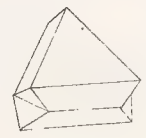

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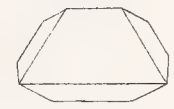

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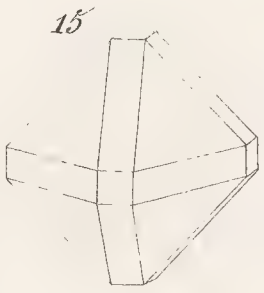

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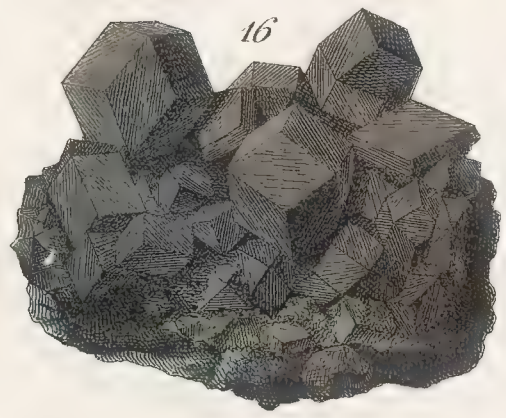

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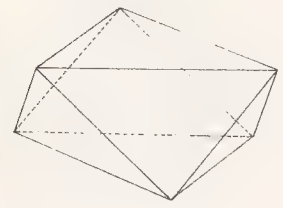

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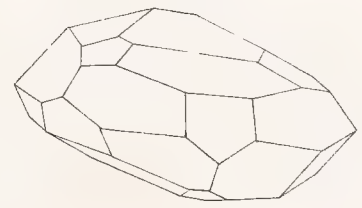

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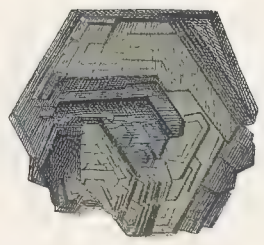

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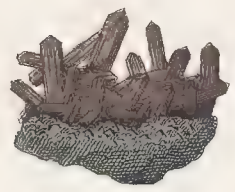

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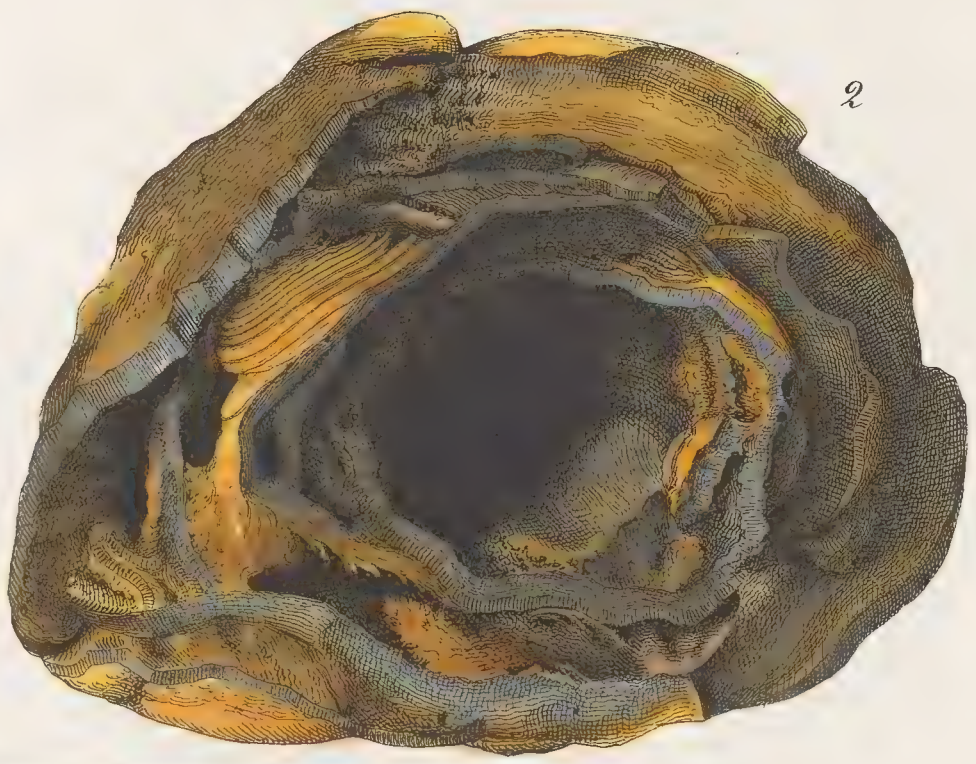

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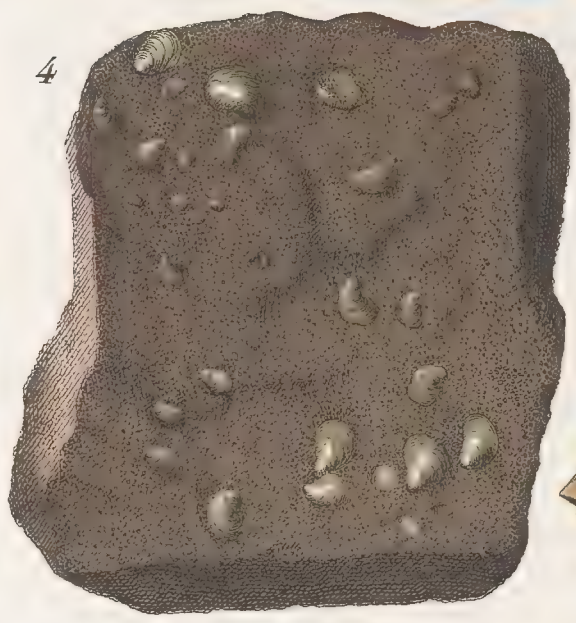

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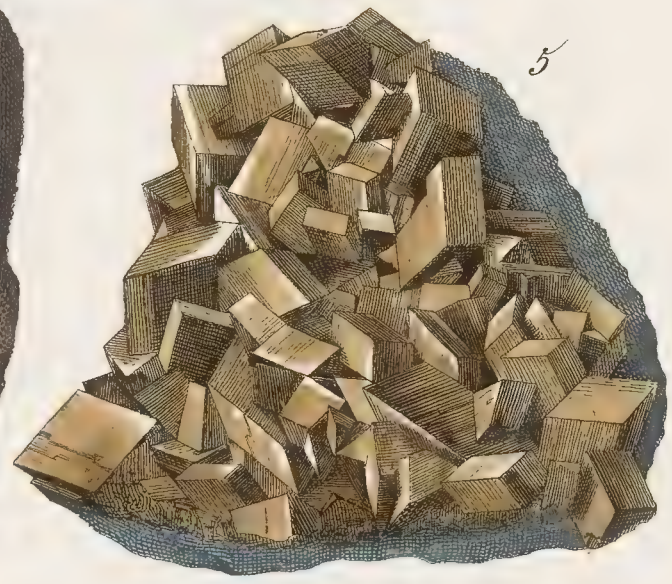

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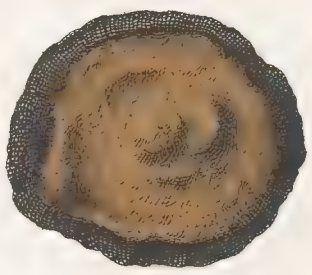

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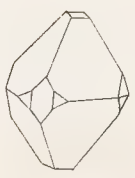

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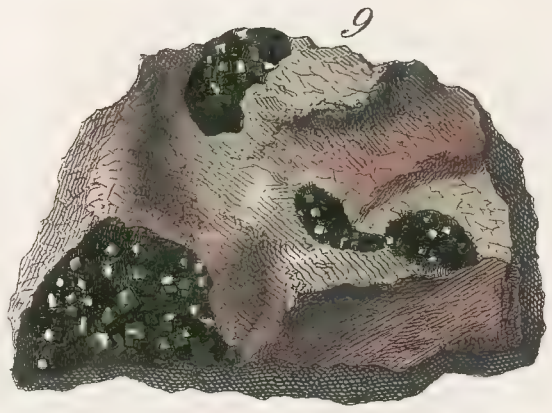

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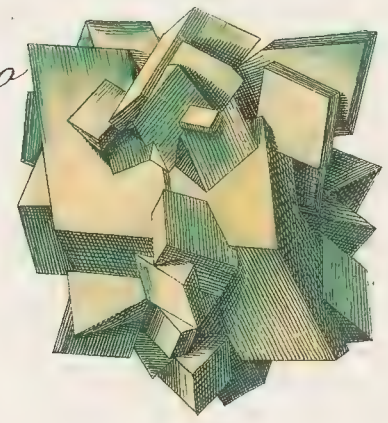

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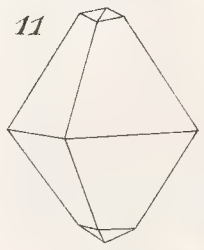

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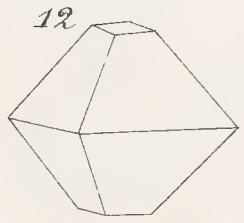

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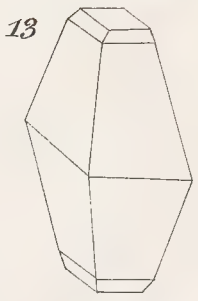

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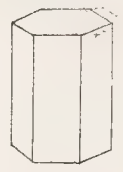

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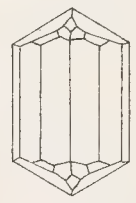

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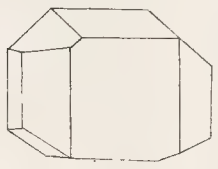

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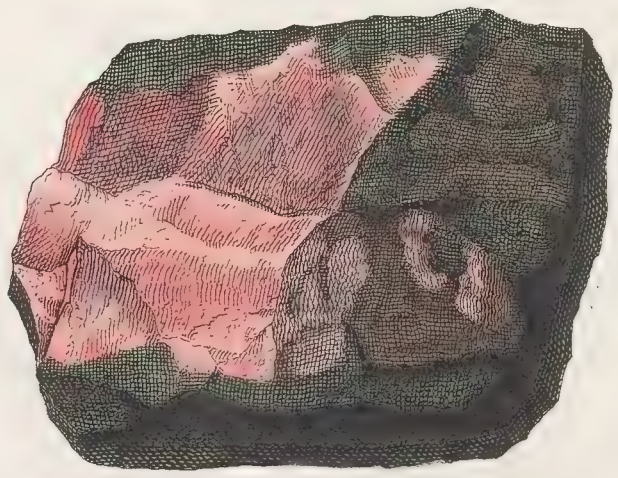

PLATE XIX.

FIGS. 1—10.—BROWN IRONSTONE AND OTHER ORES OF IRON.

1. *Stalactitic hematite*, of radiated fracture, from Brazil.
2. *Kidney-shaped Iron Ore*, scaly, and partially covered by red-ochre, from Saxony.
3. *Pea-Iron Ore*, enclosed in calcareous clay, from Salmendingia.
4. *Finely granular lenticular clay Ironstone*, with small petrifactions (*avicula elegans*), from the brown Jura of Wasseralsingen, from Würtemberg.
5. *Spathic Iron Ore*, carbonate of iron crystallised in rhombohedrons, the primary form, from Neudorf in the Harz.
6. *Bog-Iron Ore* (basic phosphate of iron), kidney-shaped, from Lake Onega in Russia.
7. *Vivianite*, or phosphate of the protoxide of iron, in oblique rectangular prisms, with truncation of the longitudinal and lateral edges, from Auvergne.
8. *Scorodite*, arseniate of iron, with four equivalents of water, from Schwarzenburg.
9. *Cube Iron Ore*, arseniate of iron, with eighteen equivalents of water, from Schwarzenberg in Saxony.
10. *Copperas*, proto-sulphate of iron, in oblique rhombic prisms, obtained from the natural salt of Graul, near Schwarzenberg, by crystallisation.

FIGS. 11—19.—HAUSMANNITE, OR MANGANESE ORE.

11. *Hausmannite*, red oxide of manganese, primary form, the quadratic octahedron, at the points in combination with a second lower octahedron, from Ihlefeld in the Harz.
12. *Braunite*, oxide of manganese, primary form, a quadratic octahedron truncated at the angles, from Ilmenau in Thuringia.
13. *The same*, a more acute quadratic octahedron in combination with the obtuse octahedron, and truncated at the points, from the same locality.
14. *Manganite*, hydrous oxide of manganese, a rhombic prism, with truncation of the acute lateral edges, from Ihlefeld in the Harz.
15. *The same*, the lateral edges of the rhombic prism doubly truncated or bevelled, and the basal edges and angles likewise truncated, from Ihlefeld.
16. *Pyrolusite*, binoxide of manganese, primary form, a rhombic prism, with truncation of the lateral edges, and of the obtuse and acute angles, an oblong octahedron, from Ilmenau.
17. *The same*, radiately foliated, in compact masses, from the same locality.
18. *Psilomelane* binoxide of manganese, containing baryta or potash, in globular, clustery masses, from Siegen in Nassau.
19. *Rhodonite*, or *Manganese Spar*, silicate of manganese, from Kapnik in Hungary.

PLATE XX.

Figs. 1—3.—Galena, Sulphuret of Lead.

1. *Galena*, hexahedral or simple sulphuret of lead, primary form, the cube on quartz, from Derbyshire.
2. *The same*, the cube, with truncation of the edges (rhombic dodecahedron), and of the angles (octahedron), from Neudorf in the Harz.
3. *The same*, the cube (H), octahedron (O), rhombic dodecahedron (D), and pyramidal octahedron, double truncation of the angles of the cube (I), from Neudorf.

Figs. 4—8.—White Lead Ore, Cerusite.

4. *White Lead Ore*, carbonate of lead, rhombic tables, united as twins, on galena, from Przibram in Bohemia.
5. *The same*, rhombic octahedron, with truncation of the acute lateral edges, the hexagonal double pyramid, from Badenweiler in Upper Baden.
6. *The same*, rhombic prism, primary form, with truncation of the acute lateral edges (the hexagonal prism), and of all the basal edges (combination with the hexagonal pyramid), from the same locality.
7. *The same*, with predominance of each of the two lateral and basal planes.
8. *The same*, the same form, six crystals aggregated in a stellate figure, from Badenweiler.

Figs. 9—11.—Anglesite, Sulphate of Lead.

9. *Anglesite*, a right rhombic prism, the primary form, with truncation of the basal angles (oblong octahedron) from Iglesias in Sardinia.
10. *The same*, a rhombic table, with truncation of the obtuse angles, from the same locality.
11. *The same*, combination of the rectangular and rhombic octahedron with the rhombic prism, whose acute lateral edges are truncated.

Figs. 12—15.—Pyromorphite, Phosphate of Lead, Arseniate of Lead.

12. *Yellow Arseniate of Lead*, or *Kampylite*, in barrel-shaped curved crystals, from Caldbeck in Cumberland.
13. *Pyromorphite Phosphate of Lead*, primary form, a hexagonal prism, from Ems in Nassau.
14. *Yellow Arseniate of Lead*, hexagonal double pyramid, with truncation of the vertex, from Joachimsthal in Bohemia.
15. *The same*, hexagonal prism, with truncation of the basal edges, from the same locality.

Fig. 16.—Molybdate of Lead, Yellow Lead Ore.

16. *Yellow Lead Ore, Wulfenite*, in square tables, in part with truncation of the basal edges (square octahedron), from Bleiberg in Carinthia.

Fig. 17.—Chromate of Lead, Red Lead Ore.

17. *Red Lead Ore, Crocoisite*, tabular, and in oblique rhombic prisms, from Beresowsk in Siberia.

Figs. 18—22.—Tin Ore, Oxide of Tin.

18. *Cassiterite, Tin Ore*, in quadratic prisms, partly with truncation of the lateral and basal edges, from Ehrenfriedersdorf.
19. *The same*, twins of quadratic lentils, from Altenberg in Saxony.
20. *The same*, quadratic prism, with truncation of the basal and lateral edges, and of all the angles, from St. Agnes in Cornwall.
21. *The same*, quadratic octahedron with the quadratic prism, from the same locality.
22. *Wood Tin*, fibrous oxide of tin, also from the same locality.

Figs. 23—27.—Zinc Ores.

23. *Blende*, the primary form, the rhombic dodecahedron with the octahedron, from Kapnik.
24. *Foliated red Oxide of Zinc*, with zinc iron ore, *franklinite*, in regular octahedrons, with truncation of the edges, imbedded in compact zinc ore, from Franklin in New Jersey.
25. *Carbonate of Zinc, Galmey*, or *Calamine*, drusy, in aggregations of rhombohedrons of compact calamine, from Altenberg near Aachen.
26. *The same*, the middle and obtuse rhombohedron.
27. *Siliceous Oxide of Zinc*, a right rhombic prism, with truncation of the angles and of the obtuse lateral edges, from the same locality.

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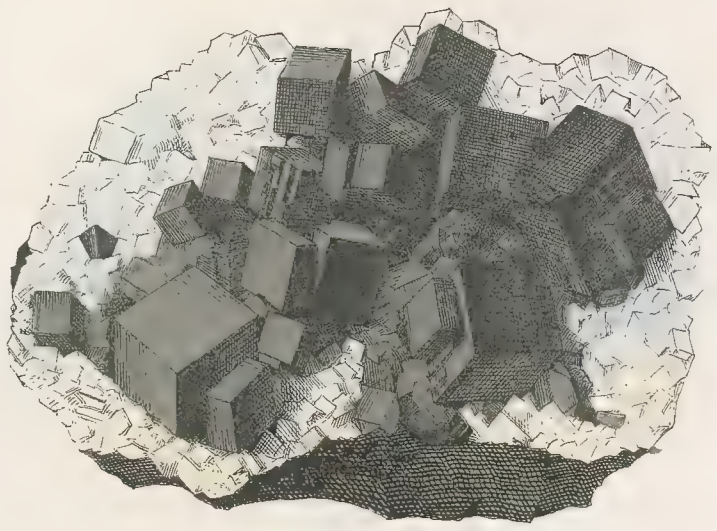

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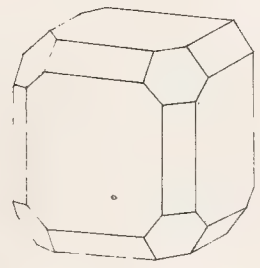

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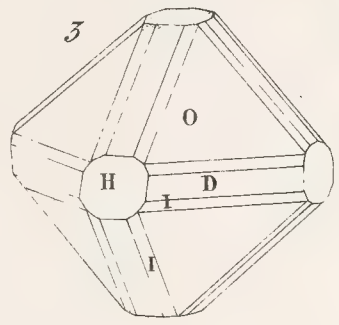

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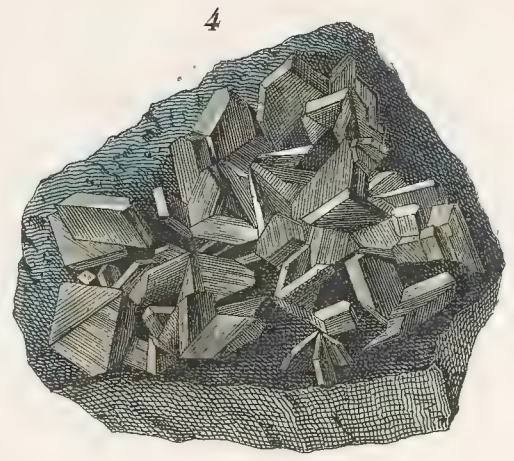

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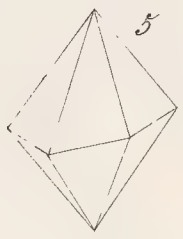

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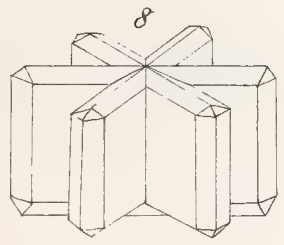

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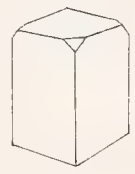

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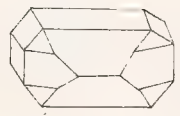

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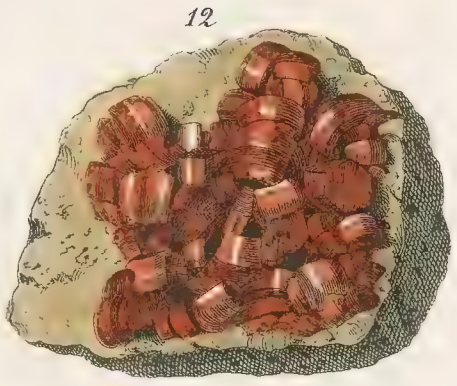

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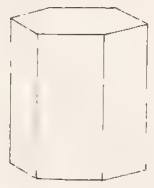

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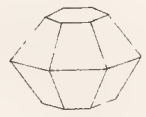

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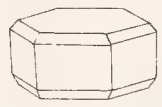

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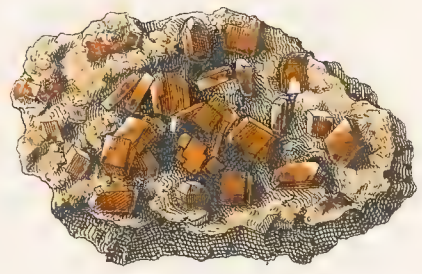

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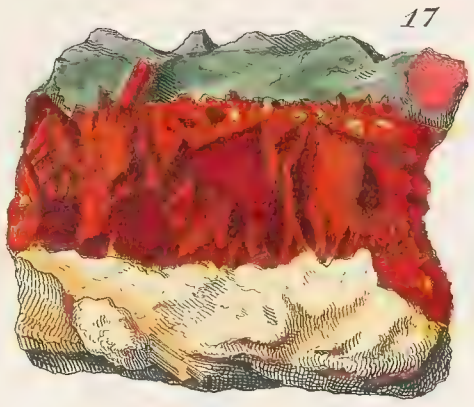

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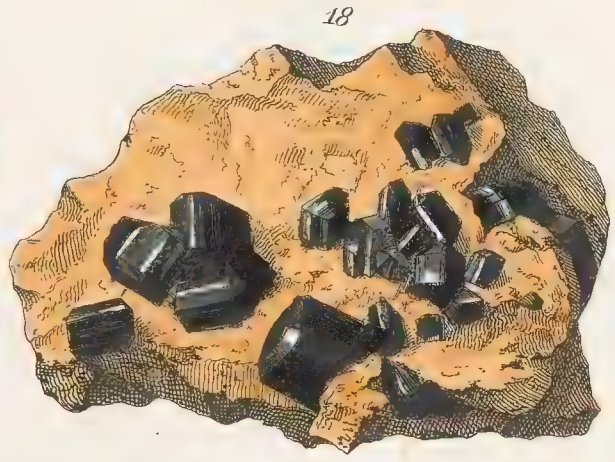

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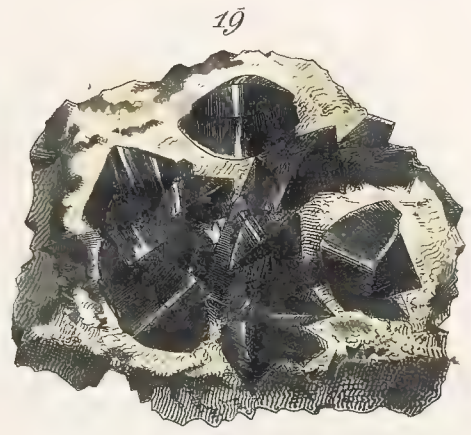

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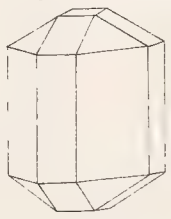

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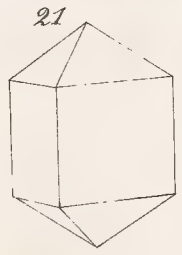

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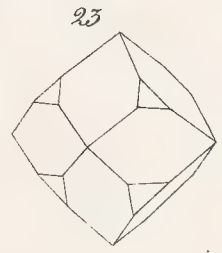

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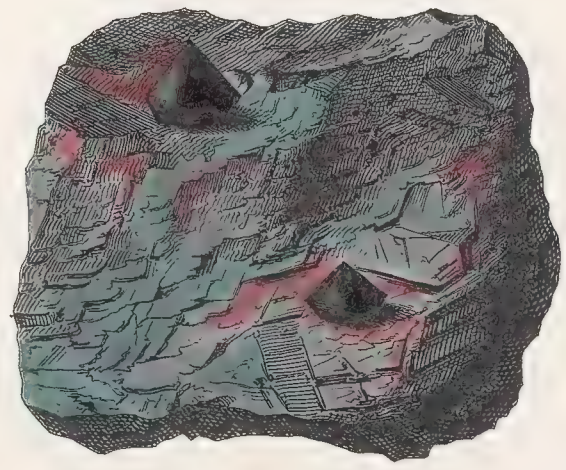

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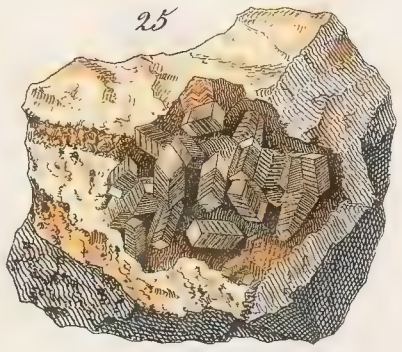

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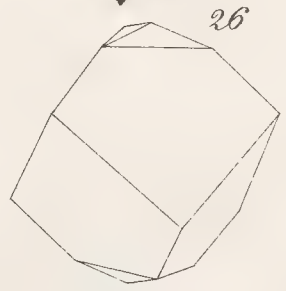

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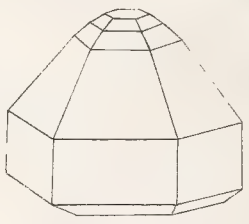

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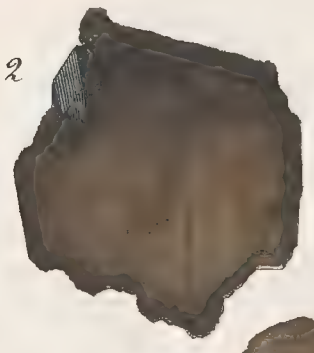

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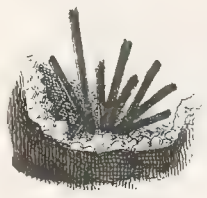

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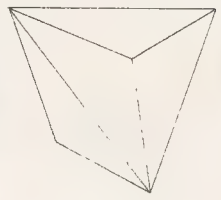

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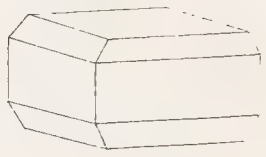

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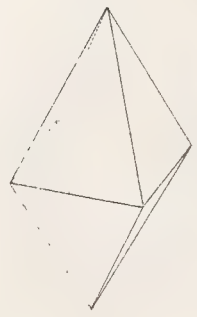

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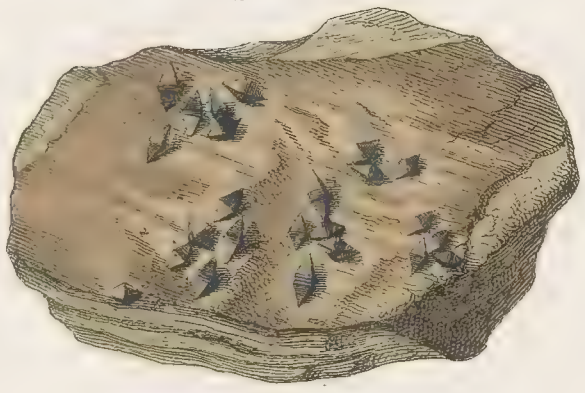

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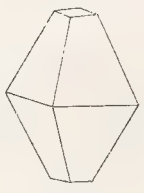

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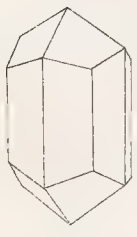

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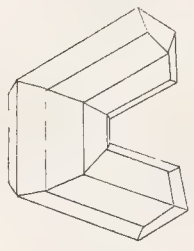

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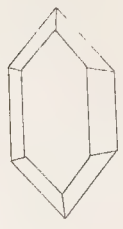

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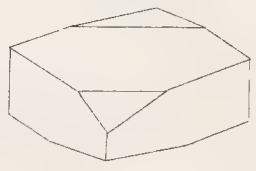

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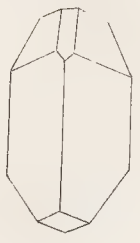

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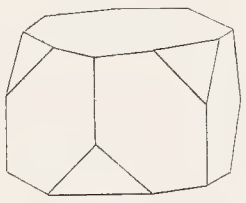

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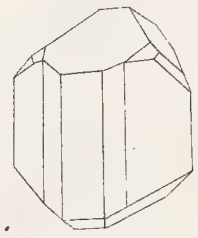

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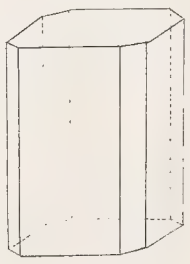

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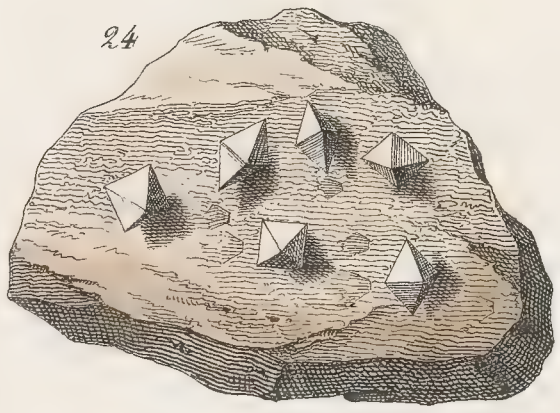

PLATE XXI.

1. *Greenockite*, sulphuret of cadmium, hexagonal prism, below with simple and above with triple truncation of the basal edges, increased in size, from Bishoptown, near Paisley.

Fig. 2—6.—Bismuth Ores.

2. *Native Bismuth*, foliated crystalline, with rhombohedral structure, from Redruth in Cornwall.
3. *Metallic Bismuth*, obtained artificially, in cube-like scalariform rhombohedrons, with an iridiscent tarnish.
4. *Native Bismuth*, streaked, imbedded in compact grey cobalt, the so-called bismuth-cobalt, from Schneeberg.
5. *Bismuthine*, containing copper, in right rhombic prisms, on horn-stone, from the Daniel mines at Schneeberg in Saxony.
6. *Eulytine*, or *Bismuth-blende*, the most common form, a pyramidal tetrahedron, increased in size, from Schneeberg.

Fig. 7—12.—Uranium Ores.

7. *Pitch-blende*, the protoxide of uranium, botryoidal and compact, from Johann-Georgenstadt in Saxony.
8. *Uran-ochre*, hydrous oxide of uranium, or carbonate of urania, from Johann-Georgenstadt.
9. *Lime-Uranite*, or *Yellow-Uranite*, in quadratic tables, with truncation of the basal edges, from Autun in France; whence it is also called *Autunite*.
10. *Green Uranite, chalcolite*, emerald-green, in quadratic tables, partially truncated at the edges, on red hornstone, from Johann-Georgenstadt.
11. *The same*, a quadratic prism with truncation of the lateral edge, the square octahedron.
12. *The same*, quadratic octahedron, with truncation of the vertex.

Fig. 13—21.—Titanium Ores.

13. *Anatase*, or *octahedral oxide of titanium*, an acute quadratic octahedron, the primary form.
14. *The same*, the square octahedron partially combined with the prism, by truncation of the basal edges, on quartz from St. Gothard.
15. *The same*, square octahedron, with truncation of the vertex, from Bourg d'Oisans in Dauphinée.
16. *Rutile*, or *prismatic oxide of titanium*, an octagonal prism, the quadratic prism truncated at the lateral edges, with truncation of the basal angles.
17. *The same*, the crystalline forms aggregated as triplets, from St. Gothard.
18. *Brookite, rhombic oxide of titanium*, a right rhombic prism with truncation of the obtuse lateral edges, and in combination with the rhombic octahedron, from Snowdon in North Wales.
19. *Sphene, Titanite*, the titanate and silicate of lime, an oblique rhombic prism, the primary form, with truncation of the obtuse base angles, from St. Gothard.
20. *The same*, with truncation of the acute angles, from Lisenz in the Tyrol.
21. *Ilmenite*, rhombohedral titanate of iron, the primary form, a rhombohedron with truncation of the vertex and of the basal edges (hexagonal prism), from the Ilmengebirge, near Miask.

Fig. 23.—Tantalum Ore.

22. *Tantalite* (Niobite, Columbite), right rhombic prism with truncation of the lateral edges (rectangular prism), the most usual form of tantalite, from Bodenmais.

Figs. 22 and 24.—Wolfram Ores.

23. *Wolfram, prismatic Scheelite*, the primary form, a right rhombic prism with double truncation of the obtuse lateral edges, and of the basal angles and edges, the most usual form of *scheelite*, from Zinnwald.
24. *Tungsten, tungstate of lime*, a quadratic octahedron, the primary form, on quartz from Zinnwald.

PLATE XXII.

Figs. 1 and 2.—Molybdenum Ores.

1. *Molybdenite, sulphuret of molybdenum*, with some molybdenic ochre imbedded in quartz, from the Valais.
2. *Molybdenite*, primary form, a six-sided prism.

Figs. 3 and 4.—Chrome Ores.

3. *Chromic Ochre* (oxide of chromium), with chromic ironstone, from Baltimore in the United States.
4. *Chromic Ironstone*, primary form a regular octahedron.

Fig. 5—10.—Antimony Ores.

5. *Native Antimony*, rhombohedron the primary form, with truncation of the basal edges, from Allemont in France.

6. *Grey Antimony, antimony glance, or stibine*, a rhombic octahedron, the primary form, with truncation of the basal edges, of the obtuse lateral edges, and double truncation of the obtuse basal angles.

7. *The same*, rhombic prism, with truncation of the obtuse lateral edges, in combination with the rhombic octahedron, the crystals are curved, foliated, and striated longitudinally, from Wolfsberg in the Harz.

8. *The same*, in radiating bundles, from Przibram in Bohemia.

9. *Red Antimony, kermesite*, oblique rhombic needles, with a radiating arrangement, on quartz, from Bräunsdorf in Saxony.

10. *Oxide of Antimony, valentinite*, octahedral white antimony in regular octahedra, of adamantine lustre, arranged in a cluster, from Qued-Hamimim in the province of Constantine.

Fig. 11—20.—Arsenic Ores.

11. *Native Arsenic*, scaly, massive, curved, and foliated, from Andreasberg in the Harz.

12. *Orpiment*, or *yellow sulphuret of arsenic*, the sesqui-sulphuret of arsenic, crystalline and foliated, from Turkey.

13. *The same*, a right rhombic prism, the primary form, with truncation of the obtuse angles and of the acute lateral edges, from Kapnik.

14. *The same*, similar crystals on chalky marl, from Neusohl in Hungary.

15. *Realgar*, simple sulphuret of arsenic, an oblique rhombic prism, the primary form, with truncation of the obtuse basal edges and of the lateral edges, from Kapnik.

16. *The same*, several such crystals on chalk marl from the same place.

17. *Mispickel*, in right rhombic prisms, the primary form; some crystals on the outside show the truncation of the obtuse, others that of the acute angles, partly in combination with truncation of the obtuse lateral edges; from Freiberg in Saxony.

18. *Arsenic-bloom, arsenious acid, white arsenic*, in regular octahedrons and tetrahedrons, the product of subterraneous fire, from Auvergne.

19. *Pharmacolite*, arseniate of lime, an oblique rectangular prism the primary form, with truncation of the obtuse lateral edges and of the basal edges.

20. *The same*, in radiated needles aggregated in bundles, partly reddened by arseniate of cobalt, from the old cobalt mines near Wittichen, in the Black Forest of Würtemberg.

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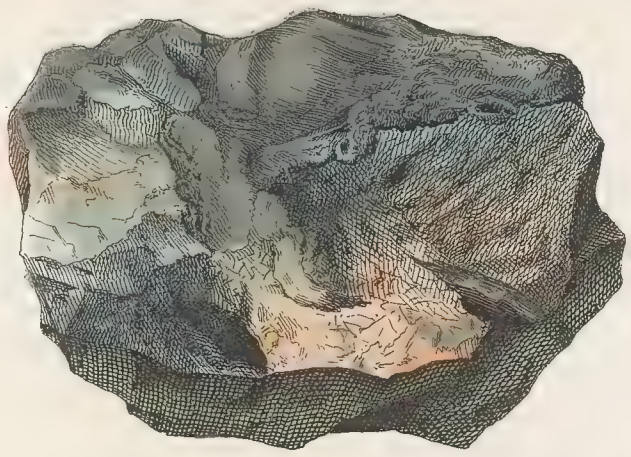

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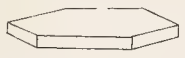

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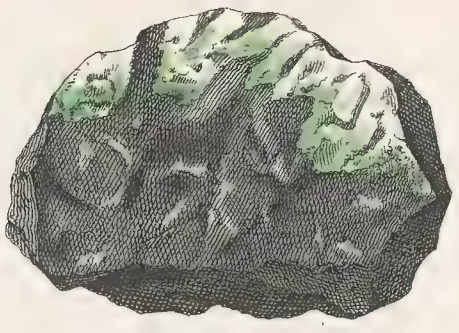

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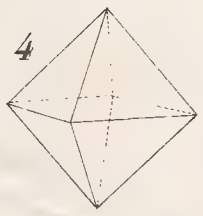

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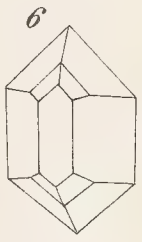

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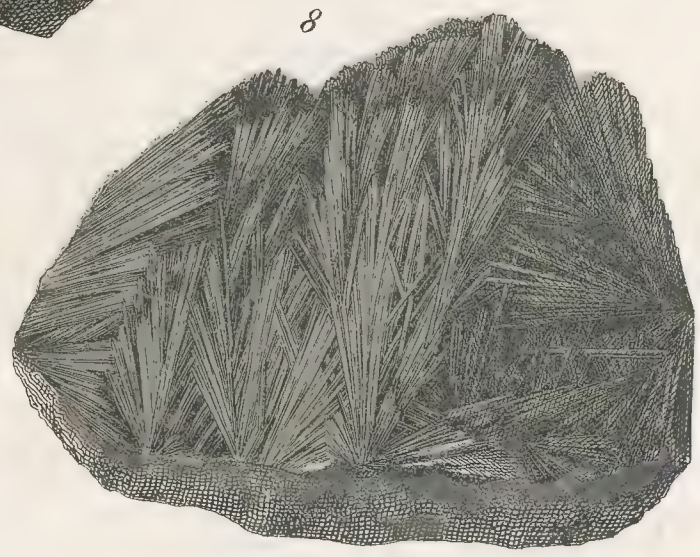

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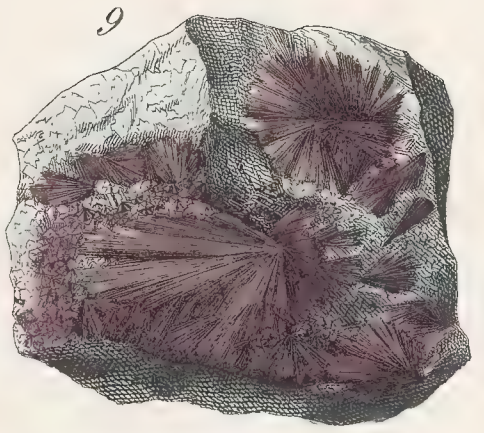

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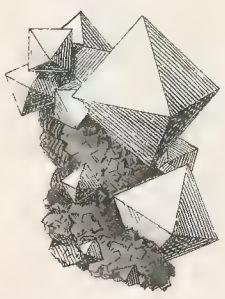

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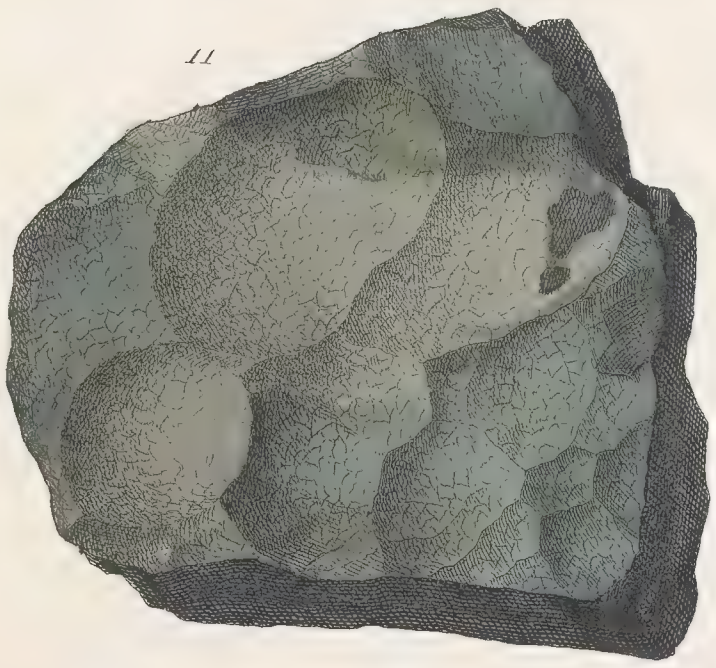

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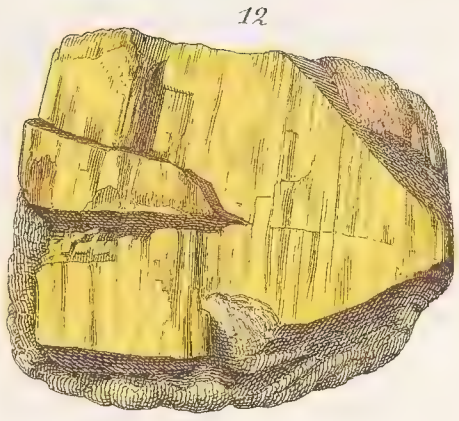

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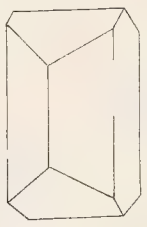

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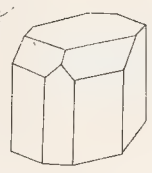

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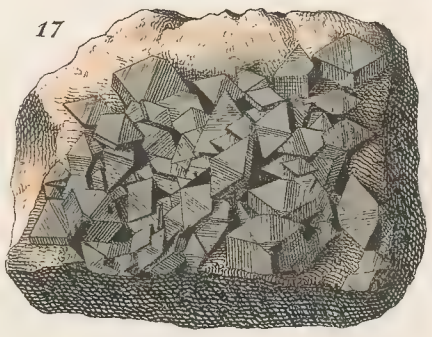

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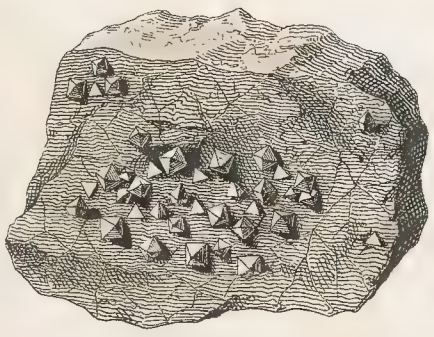

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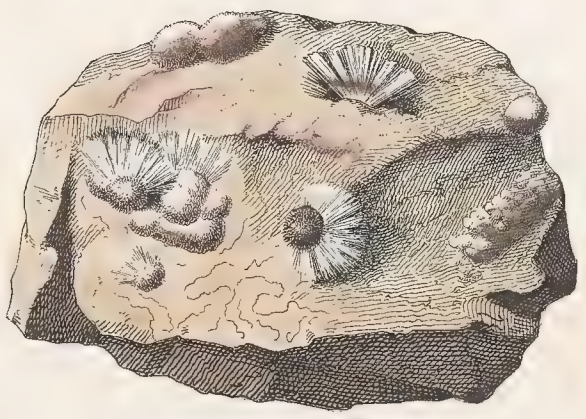

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